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PREFACE

In Volume I of the Report, we emphasised the need for planned development of water resources. Large schemes for water storage involve processes which are often irreversible, and leave little opportunity for subsequent correctives except at a prohibitive cost. Besides, there is also a limit to the total number of available dam sites. The absence of a coordinated strategy and planning can lead to a waste of resources, and impose severe limitations on the benefits which might otherwise have accrued from them.

2. An integrated water policy calls for attention to irrigation, drainage, navigation, flood control, hydroelectric power generation, water-supply for industrial and domestic use, soil conservation, land reclamation, control of water pollution from human, animal and industrial wastes, pisciculture, recreation, and control of ground water levels. If any one of these factors is dealt with in an isolated manner, serious conflicts and losses may result.

3. We also indicated that planning for the development of water resources cannot be rigid. The demand for water and its availability, change with the time and conditions and it is necessary to maintain an intelligent flexibility in planning, to keep pace, not only with changing circumstances, but also with the latest development in technology.

4. The planning of water resources has to be related to a defined area or region, with due regard to inter-regional needs. A river basin, and in the case of large rivers, a sub-basin, is a natural unit. It has a defined watershed boundary, and within it there is a certain physical homogeneity and an inter-relationship between the surface and ground water resources. A river basin, therefore, becomes a suitable unit for planning. An overall plan for the development of water resources requires not only full knowledge of the quantity, quality, and distribution of water resources, but also an evaluation of land uses and their effects on stream flows and the production and movement of sediments.

5. We have, therefore, made an attempt to collect, collate and compile the data available for each river basin or a sub-basin in the case of a big river like the Ganga. This Volume is the result of that effort. It has been split into two Parts for easy handling.

6. The figures of area proposed to be irrigated by new schemes or the water utilisation given in this Volume should not be construed to convey any acceptance of the schemes either by the Irrigation Commission, the Ministry of Irrigation & Power or the State Governments. Most of the rivers are inter-State and the final shape of new schemes will, therefore, depend upon inter-State agreements or accord. Where Tribunals have been constituted the schemes have to fit in with the award.

7. In compiling the statistics for each basin, the Commission has been somewhat handicapped. The agricultural statistics give information only by districts. In order to get an idea of the land use and area irrigated within each basin, the figures of districts which lie partially in the basin, have had to be worked out on the basis of proportional statistics (the ratio of the area in the basin to the total area of the district). The figures for each basin are therefore only approximate.

8. The water use or water utilisation and the reservoir losses in each basin have been worked out on a rough basis. Actual quantities of water diverted by the various projects have not always been available and in the absence of such information, the utilisation has been worked out on the basis of '*duties*' and '*delta*' prevalent in the area.

9. As observed by me in the preface to the second volume of the Report, the third volume on the River Basins had to be completed under the same limitations as the second volume. We had to race against time and if there are shortcomings left they were beyond our control.

New Delhi
30th June 1972

(Ajit Prasad Jain)

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INTRODUCTION

The Ganga basin with a drainage area of nearly 861,400 sq. km. in India covers slightly more than one-fourth (26.3 per cent) of its total geographical area and is the biggest river basin in the country. Stretching from the Uttar Kashi district of Uttar Pradesh, the basin covers practically the whole of northern India between the Himalayas and the Vindhyas except the State of Jammu and Kashmir. The basin covers the whole of Uttar Pradesh and the Union Territory of Delhi and parts of Punjab, Haryana, Himachal Pradesh, Rajasthan, Madhya Pradesh, Bihar and West Bengal. Outside India, the basin covers areas in Nepal, Tibet and Bangladesh. The main river, rising in the northernmost part of Uttar Pradesh, flows through Uttar Pradesh, Bihar and West Bengal and finally falls into the Bay of Bengal, south of Calcutta. The basin lies approximately between 73°30′–89°E longitudes and 22°30′–31°30′N latitudes. The Padma, which is one arm of the Ganga in its deltaic stage, flows through Bangladesh. The Statewise distribution of the basin (within India) is given below:

Uttar Pradesh	294,364 sq. km.	(34.2%)
Himachal Pradesh	4,317 sq. km.	(0.5%)
Punjab and Haryana	34,341 sq. km.	(4.0%)
Rajasthan	112,490 sq. km.	(13.0%)
Madhya Pradesh	198,962 sq. km.	(23.1%)
Bihar	143,961 sq. km.	(16.7%)
West Bengal	71,485 sq. km.	(8.3%)
Union Territory of Delhi	1,484 sq. km.	(0.2%)
Total	861,404 sq. km. or say 861,400 sq. km.	(100.0%)

2. The Ganga Basin is bounded on the north by the Himalayas and on the south by the Vindhyas. The ridge between the Indus system and Ganga system, the Great desert of Rajasthan and the Aravalli hills form the boundary on the west. The basin is widest where the main river and its tributaries like the Yamuna and the Chambal originate. The Ganga rises at 31°N latitude while the Chambal rises at about 23°N latitude. The plateau of Central India, which projects into the basin, restricts its

width. This width is the narrowest at the Rajmahal hills in Bihar, where the river turns southwards. The Ganga delta begins at this point where the river bifurcates—one arm bearing the name of Padma flows into Bangladesh and the other bearing the name of Bhagirathi flows through West Bengal into the sea.

3. The Ganga basin has been a centre of human civilisation since times immemorial and the waters of the Ganga and its tributaries have been used for agriculture for many centuries. The fertility of the Gangetic plains in Uttar Pradesh, Bihar and West Bengal has been in no small measure due to the fine alluvium deposited by the river.

THE RIVER SYSTEM

4. The Bhagirathi, which is traditionally known as the source of the Ganga, rises in the Gangotri glacier in the Himalayas at an elevation of about 7,010 m. above mean sea level in the Uttar Kashi district of Uttar Pradesh. After its confluence with the Alaknanda at Dev Prayag, the river assumes the name of 'Ganga'. After draining the middle ranges of the Himalayas the river debouches into the plains at Hardwar. From Hardwar down to Allahabad—a distance of about 720 km.—it flows in a generally south/south-easterly direction. Lower down, the river bears eastwards and flows past Varanasi to enter Bihar just below Ballia. The length of the river in Uttar Pradesh is about 1,450 km. In Uttar Pradesh the Ganga receives a number of tributaries on both banks. Of the left bank tributaries, the Ram Ganga and the Gomti are the most important. The Yamuna joins the Ganga on its right bank at Allahabad. The Tons and the Karamnasa are other right bank tributaries in Uttar Pradesh and on the borders of Bihar and Uttar Pradesh.

5. After leaving Uttar Pradesh, the Ganga forms the boundary between U.P. and Bihar for a length of about 110 km. and in this reach the Ghaghara joins it near Chapra. The river then enters Bihar and flows more or less through the middle of the State. During its course of nearly 445 km. in Bihar, the river flowing eastwards receives a number of major tributaries on both banks. The Great Gandak, the Burhi Gandak, the Bagmati and the Kosi which are all major rivers, join it on the left bank and the Son, the Pun Pun, the Kiul, the Chandan, the Gerua and others on the right bank.

6. Entering West Bengal, the river swings round the Rajmahal hill range opposite Manihari Ghat and flows almost due south. The delta of the Ganga can be said to start from Farakka. The river divides into two

arms about 40 km. below Farakka. The left arm known as the Padma flows eastwards into Bangladesh while the right arm, known as the Bhagirathi, continues to flow in a southerly direction in West Bengal. After Nabadwip it is known as the Hooghly. The river ultimately flows into the Bay of Bengal about 145 km. downstream of Calcutta. The length of the river (measured along the Bhagirathi and the Hooghly) during its course in West Bengal is about 520 km. Important tributaries to join the river in West Bengal are the Ajay, the Dwarka, the Damodar, the Rupnarayan and the Haldi.

7. The Ganga basin is so vast that the physiography, the climate, the soils, the agricultural development and allied characteristics are naturally different in different regions. For a study of problems concerned with agricultural and irrigation development in various regions, the basin has been divided into the following sub-basins:

(i) Chambal sub-basin.
(ii) Yamuna sub-basin (excluding Chambal).
(iii) Ramganga sub-basin.
(iv) Tons, Karamnasa and other rivers between Yamuna and the Son.
(v) Gomti, Ghaghara and other rivers between them.
(vi) Son.
(vii) Gandak and other left bank tributaries up to International border.
(viii) Right bank tributaries east of Son.
(ix) Main Ganga.

8. The Chapters that follow deal with the individual sub-basins in detail.

SALIENT FEATURES OF THE CHAMBAL BASIN

(i) Source: Near Mow in Indore district of Madhya Pradesh (Latitude 22°28′N, Longitude 75°40′E).

(ii)	Length: Madhya Pradesh	320 km.	199 miles
	Rajasthan	226 km.	140 miles
	Common Boundary between Madhya Pradesh & Rajasthan	251 km.	156 miles
	Common Boundary between Madhya Pradesh and Uttar Pradesh	117 km.	73 miles
	Uttar Pradesh	46 km.	28 miles
	Total	960 km.	596 miles

(iii)	Drainage area		
	Madhya Pradesh	57,948 sq. km.	22,374 sq. miles.
	Rajasthan	80,670 sq. km.	31,146 sq. miles.
	Uttar Pradesh	850 sq. km.	329 sq. miles.
	Total	139,468 sq. km.	53,849 sq. miles.

(iv)	Population (1971 Census)	15.35 millions.	
(v)	Density of population	110 per sq. km.	285 per sq. mile
(vi)	Average annual run-off	24,312 m.cu.m.	19.71 MAF

		Thousand hectares	Thousand acres
(vii)	Culturable area (1967-68)	10,140	25,057
(viii)	Net area sown (1967-68)	6,540	16,161
(ix)	Gross area sown (1967-68)	7,242	17,896
(x)	Net area irrigated (1967-68)	886	2,190
(xi)	Gross area irrigated (1967-68)	964	2,383
(xii)	Ultimate irrigation by the major & medium projects under operation and construction in 1968-69	730	1,804

			m.cu.m.	MAF
(xiii)	Water utilisation, including reservoir losses on completion & full development of major, medium and minor projects under operation and construction at the end of 1968-69	Surface waters	8,305	6.73
		Ground Waters	5,562	4.51
		Total	13,867	11.24

CHAPTER I

CHAMBAL BASIN

The Chambal basin extends over an area of 139,468 sq. km., and lies between east longitudes 73°20′ to 79°15′ and north latitudes 22°27′ to 27°20′. Lying to the north of the Vindhya range, the basin covers large areas in the States of Madhya Pradesh and Rajasthan and a small area in Uttar Pradesh. The State-wise distribution of the drainage basin of the river is given below:

Table 1.1

Madhya Pradesh	57,948	sq. km.
Rajasthan	80,670	„
Uttar Pradesh	850	„
Total	139,468	„

1.2 The basin is bounded on the north by the ridge separating it from the Luni and Yamuna basins, on the east by the ridge separating it from the Sindh sub-basin, on the south by the Vindhya range and on the west by the Aravalli range. The basin is roughly rectangular in shape with an exit passage and has a maximum length of 560 km. in the NE-SW direction and a maximum width of 430 km. in the NW-SE direction.

THE RIVER SYSTEM

1.3 The Chambal which is the principal tributary of the Yamuna, rises in the Vindhya range near Mhow in the Indore district of Madhya Pradesh at an elevation of 854 m. at north latitude 22°28′ and east longitude 75°40′ and flows in a generally northerly direction for a length of 320 km. up to the Madhya Pradesh-Rajasthan border. In this reach, the Chamla, the Siwana and the Retam join the river from the left and the Shipra and the Chhoti Kali Sindh from the right. The river then enters Rajasthan and after flowing for a length of 38 km. turns to the right and takes a north-easterly course. At 480 km. from the source, it receives a major tributary from the right near the village of Laban, the Kali Sindh, and 22 km. below another tributary the Kural from the left. The river continues to flow in a north-easterly direction for a further distance of 40 km. when it is joined by its other major right bank tributary, the Parvati, near the village of Pali. The river then forms the common boundary between Madhya Pradesh and Rajasthan for a length of 251 km. The Banas, a major left bank tributary, joins the Chambal in this reach, near the village of Rameshwar. The river, thereafter, forms the common boundary between Madhya Pradesh and Uttar Pradesh for 117 km. and flows in a north-easterly direction up to the village of Pinahat. It then gradually bears right and flows in a south-easterly direction to enter Uttar Pradesh, north-west of the village of Chakarnagar. After flowing for 46 km. in Uttar Pradesh the Chambal outfalls into the Yamuna south-east of the village of Sahon in the Etawah district.

1.4 From the source down to its junction with the Yamuna, the Chambal has a total fall of 732 m. of which about 244 m. is in the first few km. and 122 m. in a distance of about 100 km. from Chourasigarh fort to Kota city. For the rest of its course, the river passes through flat fertile areas in the Malwa plateau and later in the Gangetic plains. The Chambal Project beginning with the Gandhisagar dam and culminating in the Kota barrage is situated in the gorge from Chourasigarh fort to Kota city. The total length of the river from the head to its confluence with the Yamuna is 960 km., of which 320 km. are in Madhya Pradesh, 226 km. in Rajasthan, 251 km. form the common boundary between Madhya Pradesh and Rajasthan, 117 km. form the common boundary between Madhya Pradesh and Uttar Pradesh and the balance of 46 km. are in Uttar Pradesh.

CLIMATE

1.5 In the year, four distinct seasons occur in the basin. They are (i) the cold weather, (ii) the hot weather, (iii) the south-west monsoon and (iv) the post-monsoon. The cold weather season commences in December and continues till the end of February. The season is characterised by its bright cloudless days and nights. The hot weather starts in March and continues up to the middle of June. The season is generally dry. The south-west monsoon sets in by the middle of June and withdraws by the first week of October. During this season, the weather is somewhat sultry and oppressive. In the post-monsoon, a few thunder-storms occur, especially in October. Thereafter, the weather clears up and dry pleasant weathei prevails throughout the basin.

Rainfall

1.6 The maximum and minimum annual precipitations in the Chambal basin vary from 1,270 mm. to 356 mm. The basin receives rainfall from south-west monsoon extending from June to September. Some light showers are received off and on during the winter months also. The average annual rainfall in the various districts lying in the Chambal basin are given in the following table.

Table 1.2

Annual Rainfall—Chambal Basin

Name of District	Average annual rainfall in m.m.
1	2
Madhya Pradesh	
Indore	980
Ujjain	892
Ratlam	896
Mandasor	825
Morena	720
Bhind	668
Dewas	1,083
Shajapur	977
Rajgarh	1,101
Guna	1,054
Shivpuri	816
Bhilsa	1,134
Dhar	833
Bhopal (Sehore)	1,245
Rajasthan	
Chitorgarh	852
Kota	886
Bundi	764
Sawai Madhopur	689
Udaipur	625
Jhalawar	1,005
Tonk	614
Bhilwara	699

Table 1.2—Contd.

1	2
Jaipur	548
Bharatpur	671
Ajmer	527
Uttar Pradesh	
Agra	656
Etawah	752

Source: Monthly and annual normals of rainfall and of rainy days (1901 to 1950)—India Meteorological Department.

1.7 There are 87 rain gauge stations in the Chambal basin of which 21 are up to the Kota dam site, 33 from the Kota dam site to the confluence of the Chambal with the Banas, 29 in the Banas sub-basin and 4 in the part of the basin extending from the Banas confluence to the Yamuna confluence. This gives an average dispersion of 1,620 sq. km. per rain gauge station. The distribution of stations is not even and their number is also not sufficient. It is suggested a few rain-gauges to obtain a balanced distribution over the entire basin should be established.

1.8 In the month of January, the mean temperature over the basin is between 15°C to 20°C. In April, the mean temperature varies from 27.5°C to 32.5°C. In the month of July too, it ranges between 27.5°C and 32.5°C. In the month of October, the basin experiences temperature between 25°C and 27.5°C.

1.9 There are two departmental and one agrometeorolagical observatories of the India Meteorological Department within the basin.* The departmental observatories are located at Dholpur and Rawat Bhatta Dam site and the agro-meteorological observatory is at Kota.

SOILS

1.10 No detailed soil survery of the basin has yet been made. However, the general data regarding the soils of India indicates that mainly medium black, mixed red and black and red and yellow soils occur in the basin. The principal soil types found in the various districts lying in the basin are given below:**

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*Evaporation Data (India), India Meteorological Department (April, 1970).

**Indian Crop Calendar, Ministry of Food, Agriculture, Community Development and Cooperation (1967).

Table 1.3

Soils of Chambal Basin

District	Type of Soil
1	2
Madhya Pradesh	
Indore	Medium black
Ujjain	Medium black
Ratlam	Medium black and mixed red and black
Mandasor	Medium black and mixed red and black
Morena	Medium black
Bhind	Medium black
Dewas	Medium black
Shajapur	Medium black
Rajgarh	Medium black
Guna	Medium black and mixed red and black
Shivpuri	Medium black and mixed red and black
Vidisha	Medium black
Dhar	Medium black
Sehore	Medium black
Rajasthan	
Chittorgarh	Red and yellow and mixed red and black
Kota	Medium black, mixed red and black and alluvial
Bundi	Medium black, mixed red and black and alluvial
Sawai Madhopur	Red and yellow and medium black
Udaipur	Red and yellow
Jhalawar	Medium black
Tonk	Alluvial
Bhilwara	Red and yellow and mixed red and black
Jaipur	Alluvial
Bharatpur	Red and yellow medium black and alluvial.
Ajmer	Mixed red and black and grey brown.
Uttar Pradesh	
Agra	Medium black and alluvial.
Etawah	Alluvial and saline.

LAND USE AND AGRICULTURAL PRACTICES

1.11 Statewise land use details in the Chambal basin in 1967–68 are given below:

Table 1.4

Land Use Details—Chambal Basin

(Thousand hectares)

Item	State			Total
	Madhya Pradesh	Rajasthan	Uttar Pradesh	
1	2	3	4	5
Geographical area	5,795	8,067	85	13,947
Reporting area	5,779	8,034	85	13,898
Area under forests	605	615	5	1,225
Area not available for cultivation	819	1,701	13	2,533
Culturable area	4,355	5,718	67	10,140
Uncultivated culturable area	1,303	2,290	7	3,600
Net area sown	3,052	3,428	60	6,540
Area sown more than once	189	497	16	702
Total cropped area	3,241	3,925	76	7,242
Net irrigated area	162	702	22	886
Gross irrigated area	168	773	24	964
Percentage of net irrigated area to culturable area	3.7	12.3	33.4	8.7
Percentage of net irrigated area to net sown area	5.3	20.5	37.3	13.6
Percentage of net area sown to culturable area	70.1	60.0	89.6	64.5

1.12 Agriculture has been practised in the Chambal basin quite extensively. Nearly 64.5% of the culturable area is cultivated annually. In the upper part of the basin in Madhya Pradesh, the percentage of cultivated area to culturable area is more than the average for the basin i.e. 70.1% whereas in Rajasthan it is less than the average i.e. 60%. The area lying in Uttar Pradesh is very small and the high percentage of cultivated area here (89.6%) does not make much difference to the average for the basin.

Area irrigated constitutes hardly 13.6% of area cultivated in the basin. The figure for Madhya Pradesh is 5.3% while it is 20.5% in Rajasthan. A characteristic feature of irrigation in the basin is the very high percentage (81.3%) of area being irrigated by tanks, wells and other minor sources. During 1967–68, only 18.7% of the net irrigated was by canals.

1.13 The general agricultural practices in the Chambal basin follow the same pattern as in the Central and north-western parts of the country. Wherever agriculture depends solely on rainfall, the normal practice is to raise kharif crops like bajra, jowar and maize during the monsoon months and wheat, barley and other rabi crops during the rabi season, making use of the moisture in the soil and the winter rainfall. Wheat and barley are grown, on an average, on 25% of the total area cultivated annually. Rice is grown very rarely and constitutes hardly one per cent of the total cultivated area.

1.14 Under irrigated conditions also, the rabi crops (wheat and barley) predominate. During 1967–68, out of a gross irrigated area of 0.964 million hectares, wheat and barley covered 0.572 million hectares (59.3%). The State-wise cropping pattern under irrigated conditions during 1967–68 was as given below:

Table 1.5

Irrigated Crops—Chambal Basin

(Thousand hectares)

Name of crop	Madhya Pradesh		Rajasthan		Uttar Pradesh		Total	
	Area	% to Total	Area	% to Total	Area	% to Total	Area	% to Total
1	2	3	4	5	6	7	8	9
Rice	2.9	1.7	12.4	1.6	1.8	7.6	17.1	1.8
Wheat & Barley	73.9	44.0	483.1	62.5	14.5	60.9	571.8	59.3
Sugarcane	6.8	4.0	7.7	1.0	0.7	2.9	15.2	1.0
Other food crops	68.1	40.8	168.7	21.8	5.2	21.9	242.0	25.0
Total food crops	151.7	90.5	671.9	86.9	22.2	93.3	845.8	87.7
Cotton	2.0	1.2	45.7	5.0	0.5	2.1	48.2	5.0
Other non-food crops	13.9	8.3	54.4	7.2	1.1	4.6	70.4	7.3
Total non-food crops	15.9	9.5	101.1	13.1	1.6	6.7	118.6	12.3
Total cropped area	167.6	100.0	773.0	100.0	23.8	100.0	964.4	100.0

Crop Seasons

1.15 There are two main crop seasons in the basin, the kharif and the rabi. The kharif season normally starts with the onset of the south-west monsoon in June and extends up to October. In this season, the lower order cereals like maize, bajra and jowar are normally grown. At the end of the S.W. monsoon in October, the rabi season starts and extends up to March-April. The crops grown during rabi are wheat, barley, pulses etc.

REGIONAL ECONOMY

Population

1.16 On the basis of the 1971 Census* and the percentages of the area of each district within the basin to the district as a whole, the total population in the basin is about 15.35 millions. The state-wise distribution is given below:

Madhya Pradesh	6.31	millions
Rajasthan	8.69	,,
Uttar Pradesh	0.35	,,
Total	15.35	,,

There are five cities in the basin which have a population of more than one lakh each (1971 Census). They are Indore and Ujjain in Madhya Pradesh and Jaipur, Udaipur and Kota in Rajasthan. The average density of population in the basin is 110 persons per sq. km. against the figure of 182 for India as a whole. The density of population is practically the same in both Madhya Pradesh and Rajasthan (being 117 and 115 persons per sq. km. respectively). Though the density in Uttar Pradesh is quite high (412 Persons per sq. km.), it does not make any material difference to the overall average, as the area of that State within the Chambal basin is very small. Within Madhya Pradesh itself, the districts of Ratlam, Ujjain, Indore and Bhind have higher than average population. In Rajasthan also. The districts of Jaipur, Ajmer and Bharatpur have higher than average population.

Of the total population, nearly 79.5% live in villages while the remaining 20.5% live in urban areas. The working force constitutes nearly 33.5%

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*Census Paper I of 1971 (supplementary), registrar-General (India).

of which 56.1% is engaged as cultivators, 19.8% as agricultural labourers. The rest of the working force is engaged in other services.

Forests and Agriculture

1.17 Except in the upper reaches of the Chambal basin where there are forests, the land in the basin is culturable. Some area along the river banks in the districts of Morena and Bhind are subject to heavy erosion which has caused ravines. Forests occupy only 8.8% of the total geographical area of the Chambal basin and the culturable area constitutes 75.0%. Out of a culturable area of 10.14 million hectares, nearly 71.4% i.e. 7.24 million hectares is cultivated annually.

Irrigation development in the basin has been very meagre. During 1967–68 hardly 13.3% of the area cultivated was provided with irrigation. The development in the Madhya Pradesh region was hardly 5.2% while in Rajasthan it was 19.7%. Irrigation was mainly provided by wells and tubewells in about 66.7% of the area irrigated annually.

Power

1.18 According to the surveys conducted by the Central Water & Power Commission, the total hydro-power potential in the Chambal basin has been assessed at 232 MW at 60% load factor. With the completion of the three reservoirs on the Chambal, viz. Gandhi Sagar, Rana Pratap Sagar and Jawahar Sagar, the full power potential in the Chambal basin would have been fully developed. The following are the installed capacities under the three power stations:

Gandhi Sagar	115 MW
Rana Pratap Sagar	172 MW
Jawahar Sagar	99 MW
Total	386 MW

An atomic power station which will have an installed capacity of 400 MW is under construction at Rana Pratap Sagar. One unit of 200 MW is expected to be commissioned during the Fourth Plan period and the other unit of 200 MW later, probably in the Fifth Plan period.

Mineral Wealth

1.19 So far as mineral wealth is concerned, the Chambal basin in

Madhya Pradesh can be said to be quite poor. Except for small deposits of Manganese ore in Indore district, lime stone deposits in Morena district and fire and china clay deposits in Mandsaur and Shivpuri districts, no minerals of any importance occur in the Madhya Pradesh region of the Chambal basin.*

Lead and Zinc: In the Udaipur district. These reserves are estimated to be 4.5 and 8 million tonnes of proved and provable ore averaging 8.5 per cent metal content.

Manganese ore: Estimated at 4 million tonnes in the Banswara (not in Chambal basin) and Udaipur districts. The ore is of low grade and the entire quantity is exported.

Lime Stone: In the Chitorgarh district.

Mica: In the Jaipur and Udaipur districts.

Feldspar: In the Ajmer and Udaipur districts.

Building Stones: The largest contribution to Rajasthan's mineral production comes from building stone, including marble and sand stones. Marble deposits in the basin are found in the Bhilwara district.

Talc: In the Bhilwara, Jaipur, Udaipur and Sawaimadhopur districts. Rajasthan produces about 90 per cent of the country's talc output.

Glass sand: In the Bundi, Kota and Sawaimadhopur districts.

Quartz: In the Ajmer and Udaipur districts.

China Clay: In the Ajmer, Kota and Udaipur districts.

Industries

1.20 Compared to many other States in India, both Rajasthan and Madhya Pradesh can be stated to be industrially backward. With the implementation of the Chambal Project and the availability of electric power, a good number of industries have come up in the Kota, Udaipur and Jaipur regions of Rajasthan. Some of the big industries which may be mentioned are the cement factory at Sawaimadhopur, the Rayon factory and the Fertiliser factory near Kota. Industries based on agriculture like textiles are also found in Kota, Jaipur, Bhilwara etc. Tobacco factories are located in the Kota and Tonk districts.

In the Madhya Pradesh region, industries are essentially based on agriculture. Cotton textile mills are located in Indore, Ujjain and Ratlam and silk mills in the Ujjain district. Industries based on forest resources, such as the paper and cardboard industries are located in the Ratlam district.

The occurrence of minerals in the Rajasthan region is as follows:**

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*Techno-Economic Survey of Madhya Pradesh, NCAER.

**Techno-Economic Survey of Rajasthan, NCAER.

Communications

1.21 Though most important towns and cities are connected by rail and road, the interior of the basin is not well served by road and railway. The basin is served by both the Central and Western Railways. The broad gauge line connecting Bombay and Delhi, both by the Western as well as the Central Railway, passes through the basin. National Highway No. 3 (Bombay-Agra) and NH No. 8 (Jaipur-Ahmadabad) pass through the basin. In addition to the above, the basin is also served by the metre gauge lines of the Central and Western railways and a number of State highways and district and other roads. The Chambal and its tributaries are not navigable and inland water transport in the basin is negligible.

WATER RESOURCES

Surface Water

1.22 The surface water potential of the Chambal river system had been first assessed in 1949 on the basis of Khosla's formula. The annual run-off of the river was estimated to be 33,908 m. cu. m.* In 1960 when the irrigation potential studies of the country were made by the Central Water and Power Commission, the total annual run-off of the Chambal river system was assessed to be 24,312 m. cu. m.** on the basis of Strange's coefficient for 'average' catchments. Prior to 1946 neither the Chambal nor its tributaries had any gauge or discharge sites on them. It was only with the taking up of the Chambal Project, that gauge and discharge observations were started on the main river in the year 1946. The gauging station was located just upstream of the Gandhisagar dam site at Sujanoura. Subsequently in 1961 five new gauging stations at the following places have been set up on the fringe of the Gandhisagar lake:

Site	*Catchment area*
Barkheda on the Chambal	6,540 sq. km.
Kalukheri on the Shipra	5,137 ,,
Chaumahala on the Choti Kali Sindh	2,716 ,,
Nahargarh on the Siwana	2,291 ,,
Tumri on the Retum	1,856 ,,

1.23 The average annual yield of the Chambal basin at the Gandhisagar dam site has been worked out as 4,502 m. cu. m. At the time of construction of the dam, as the actual gauge data was available only for a short period of seven years, rainfall records for the previous years were made use of for calculating the average yield, by using Strange's formula. Similarly the yield between Gandhisagar and Rana Pratapsagar (intermediate catchment area 2,333 sq. km.) was worked out as 450 m. cu. m. while that between Rana Pratapsagar and Kota barrage (intermediate catchment area 2,333 sq. km.) as 496 m. cu. m. Thus the total average yield of the Chambal basin up to Kota barrage (total catchment area 27,216 sq. km.) works out to 5,448 m. cu. m.

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*An appraisal of water resources by Dr. A. N. Khosla, UNESCO.

**Report on the technological possibilities of irrigation projects in India, Central Water and Power Commission (unpublished).

GROUND WATER*

Madhya Pradesh Region

1.24 The Geological Survey of India has carried out ground water surveys over an area of 2,300 sq. km. in the Bhind and Morena districts in the basin. The area surveyed lies between 180 and 200 m. above sea level with a gentle slope towards the north-east. The shallow alluvium deposited mostly over Vindhyan rocks, is generally limited to a maximum thickness of about 60 m. comprising clay, kankar, siltsand and grave. The alluvium is thicker towards the river Chambal in the north. Ground water occurs under both water table and confined conditions. The hydraulic gradients of the water table and piezometric surfaces are towards the north in the direction of the Chambal river. The river is affluent with a relatively shallow depth of alluvium, the presence of permeable granular zones of restricted thickness and lateral extents. Because of these factors and the unfavourable terrain (because of adverse topography) ground water development has limited scope.

Rajasthan Region

1.25 Ground water surveys in the districts of Udaipur, Chitorgarh, Bhilwara, Sawaimadhopur, Kota and Tonk have been carried out.

The area surveyed in the Udaipur district is underlain by precambrian crystalline rocks except for a narrow belt along the Banas river. Alluvium is confined to a narrow strip on the south bank of the Banas which has been explored for water. The strip of land covered by alluvium of less than 20 m. thick comprising of pebbles and gravel, is suitable for moderate capacity tubewells with yields of 40 to 50 kilolitres per hour. The depth of the water table is generally less than 10 m.

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*Ground Water Resources of India, States and Surveys, Prospects and Perspectives, Geological Survey of India, (August, 1970).

The greater part of the area surveyed in the Chitorgarh district is covered by lime stone and sand stone of Vindhyan age. No exploration has been carried out to ascertain the feasibility of tubewell construction in the Vindhyans. The lime stones are known to be cavernous at places. Considering that certain horizons in the Vindhyans of Jodhpur are highly potential, it is likely that exploration in the cavernous limestone areas may yield tangible results. The depth to water table generally ranges up to 10 m. but locally up to 20 m. The quality of ground water is generally good.

In the Bhilwara district, except along the banks of rivers where shallow tubewells of 15 to 20 m. may be feasible at places, the area is not suitable for significant ground water development through tubewells or open wells. Even along the rivers, development through tubewells is restricted due to the fact that the alluvial strip coincides with the present river courses.

The greater part of the Sawaimadhopur district is underlain by pre-cambrian rocks and by Vindhyans. Alluvium is restricted to the vicinity of the Banas river. Except for the alluvial fill of the river, the rest of the district is not suitable for the development of tubewells. However, exploration of the alluvial tract is yet to be carried out.

The Kota district is underlain by Vindhyan sand stones, shales and lime stones. Available information indicates that the lime stones at places are cavernous and are suitable for the construction of tubewells. Ground water surveys are in progress in the district. In parts of the Chambal command, there is waterlogging. The depth to water table in the canal command areas ranges from less than 1 to 6 m.

In the greater part of the Tonk district, ground water occurs in the pre-cambrian rocks. Alluvium is saturated along the Banas river. Shallow tubewells of less than 30 m. depth in alluvium yield 60 to 100 kilolitres per hour. This alluvial tract holds good prospects of tubewell irrigation.

A considerable part of the Chambal basin is underlain by pre-cambrian rock and possibilities for the development of ground water resources are limited. There are alluvial tracts mostly confined to strips one to two km. in width along important rivers, where the possibility of developing tubewells exists. Detailed surveys for assessing the quantum of such ground water and the feasibility of an economic exploitation of this resource for irrigation are yet to be carried out.

EXISTING DEVELOPMENT

1.26 The development of irrigation in the Chambal basin prior to 1947 was by tanks across the small streams flowing into the Chambal and its tributaries and irrigating small patches of land. There were hardly any irrigation projects of any appreciable size. In all, an area of approximately 20,000 hectares was irrigated under these tanks in Rajasthan and a similar area in Madhya Pradesh. The First Irrigation Commission had not recommended any specific projects by name to be taken up in the basin.*

After Independence efforts were begun to make use of the Chambal waters both for the generation of power and for irrigating lands in Rajasthan and Madhya Pradesh. The Chambal Project which was a joint venture of Madhya Pradesh and Rajasthan aims at the optimum utilisation of the Chambal waters for irrigation and for power production.

1.27 The Chambal Project consists of three reservoirs viz., Gandhi Sagar, Rana Pratap Sagar and Jawahar Sagar and a barrage at Kota from where the irrigation canals taffe off to irrigate 0.285 million hectares each in Madhya Pradesh and Rajasthan. The Gandhi Sagar dam is situated in Madhya Pradesh and the Rana Pratap Sagar, Jawahar Sagar and the Kota barrage in Rajasthan.

The Gandhi Sagar dam, started during the First Five Year Plan, was the first of three dams to be taken up for construction. At the dam site, the Chambal drains an area of 22,550 sq. km. The dam has a maximum height of 64 m., a length of 514 m. and a live storage capacity of 6,920 m. cu. m. Five units of 23,000 KW each have been installed in the power house of the dam.

Rana Pratap Sagar was the Second reservoir on the Chambal to be taken up for construction. The work on the dam was taken up during the Second Five Year Plan. It is located 56 km. downstream of Gandhi Sagar and drains an additional catchment area of 2,333 sq. km. The maximum height of the dam is 54 m. and the length is 1,143 m. The reservoir has a live storage capacity of 1,567 m. cu. m. Four units of 43,000 KW each have been installed in the power house of the dam.

Jawahar Sagar which is under construction is the third reservoir on the Chambal. The dam is located 23 km. below the Rana Pratap Sagar dam and drains a further area of 1,944 sq. km. This has been taken up as a power project and will have an installed capacity of 3 units of 33,000 KW each.

The lowest of the irrigation works in the Chambal Project is the Kota barrage (situated near Kota city in Rajasthan) from where the irrigation canals take off. The work on the barrage was taken up simultaneously with the Gandhi Sagar dam and was completed in 1960. The Left Bank Canal provides irrigation in Rajasthan while the Right Bank Canal irrigates lands both in Rajasthan and Madhya Pradesh. Irrigation from the project started in 1960. The full development of 0.57 million hectares is expected to be achieved by the end of the Fourth Plan.

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*Report of the Indian Irrigation Commission (1901-03).

Development of irrigation in the Chambal command has been rather slow. Even ten years after the commencement of irrigation, the area actually irrigated is nowhere near the ultimate figure of 0.285 million hectares each in Rajasthan and Madhya Pradesh. During the year 1969–70, the areas irrigated in the two States were 73,300 hectares and 62,350 hectares respectively. The reasons for the slow development are:

(i) The actual culturable command areas under the project in Rajasthan and Madhya Pradesh are 0.22 million hectares and 0.35 million hectares respectively against the originally assumed areas of 0.35 million hectares and 0.46 million hectares respectively.

(ii) The actual carrying capacity of the Right Bank Canal which is to irrigate lands both in Rajasthan and Madhya Pradesh is only 79 cumecs against the designed capacity of 188 cumecs.

The Technical Committee appointed by the Government of India in 1970 has analysed this problem and has concluded that:

(i) excessive weed growth in the canal;

(ii) flatter water gradients assumed in the design;

(iii) excessive fluming of the canal at regulators and other points;

are primarily responsible for the low carrying capacity of the canal. The Committee has also suggested methods to overcome these difficulties. They are:

(i) Bypassing of five tanks in the head reach of canal which have become breeding and stocking places for weeds.

(ii) Remedying the structural defects in various structures.

(iii) Preventing and eradicating weed growth in the canal.

It is expected that these remedies will improve the performance of the canal and that irrigation development will be much faster than hitherto.

1.28 In addition to the Chambal Project, a number of medium schemes have also been undertaken and completed both in Madhya Pradesh and in Rajasthan during the Plan period. Details of the medium projects with an irrigation potential of 4,040 hectares and above under operation and construction in the basin (including pre-Plan projects) are given in Table 1.6.

1.29 All the medium projects so far completed (inclusive of pre-plan schemes) and those in hand will provide irrigation to an area of 0.163 million hectares. Adding to this, 0.567 million hectares to be done under the Chambal Project, the total irrigation on full development from all the major and medium schemes—both completed and those under-construction—in the basin will be 0.73 million hectares.

1.30 Against an ultimate area of 0.73 million hectares to be irrigated

Table 1.6

Projects Completed and Under Construction—Chambal Basin

Name of Project	Location (district)	Date of completion	Estimated cost Rs. million	Ultimate irrigation (hectares)
1	2	3	4	5
Madhya Pradesh				
(i) *Completed Projects*				
(A) ***Pre:Plan Projects***		NIL		
(B) *Plan Projects*				
1. Chillar (Tillar)	Shajapur	1970-71	15.26	5,260
2. Projects irrigating less than 4,040 hectares (4 Nos.)			13.85	6,100
(ii) *Projects under construction*				
1. Projects irrigating less than 4,040 hectares (2 Nos.)			12.99	4,110
Total Madhya Pradesh			42.10	15,470
Rajasthan				
(i) *Completed Projects*				
(A) *Pre-Plan Projects*				
1. Morel	Sawai Madhopur	N.A.	3.10	9,710
2. Projects irrigating less than 4,040 hectares (7 Nos.)			8.29	13,150
(B) *Plan Projects*				
1. Gambheri	Chitorgarh	1956	6.90	5,460
2. Namano	Udaipur	1957	5.75	4,450
3. Meja	Bhilwara	1956	9.70	9,710
4. Sareri	,,	1957	3.91	5,260
5. Arcar	,,	1958	5.00	4,860
6. Galwa	Tonk	1960	4.10	5,260
7. Gudha	Bundi	1958	7.22	8,090
8. Parvati	Bharatpur	1959	12.20	12,140
9. Moral	Sawai Madhopur	1954	5.20	6,560
10. Parwan	Kota	1960	2.30	4,040

Table 1.6—Contd.

1	2	3	4	5
11. Projects irrigating less than 4,040 hectares (19Nos).			38.72	28,270
(ii) *Projects under construction*				
1. Kalisindh	Jhalawar	IV Plan	7.30	8,090
2. Meja feeder	Bhilwara	N.A.	16.60	6,880
3. Projects irrigating less than 4040 hectares (6 Nos.)			34.94	15,670
Total Rajasthan			171.23	147,600
Grand Total			213.33	163,070

Sources: (i) India Irrigation and Power Projects Five Year Plans, CW&PC (April, 1970).
(ii) Note volumes on irrigation chapters for Madhya Pradesh and Rajasthan, CW&PC (1970).

under major and medium projects so far undertaken, an area of hardly 0.17 million hectares was irrigated under them during 1967–68, while the total area irrigated from all sources during the same year was 0.89 million hectares. It is thus seen that 0.72 million hectares was irrigated under minor irrigation (i.e. under tanks, wells, tubewells and other sources). The areas irrigated from various sources like canals, tanks, wells etc. during the year 1967–68 were as given below:

Table 1.7
Source-wise Irrigation—Chambal Basin

(Thousand hectares)

Source of irrigation	Area irrigated			
	Madhya Pradesh	Rajasthan	Uttar Pradesh	Total
1	2	3	4	5
Canals	32.60	120.00	12.90	165.50
Tanks	5.50	115.30	0.10	120.90
Wells (including tubewells)	119.70	462.00	9.20	590.90
Other sources	4.50	4.30	0.20	9.00
Total	162.30	701.60	22.40	886.30

1.31 Information regarding the working statistics of reservoirs is not available. However, a rough estimate has been made of the water that would be used under all major and medium projects in the basin on their completion, based on the delta and crop pattern assumed in the Chambal Project (delta for kharif crops is 0.915 m.; delta for rabi crops 0.61 m. and the kharif to rabi crop ratio is 30:70). Working on this basis for irrigating an area of 0.73 million hectares, the annual diversion of water will be 4,934 m. cu. m.

1.32 Statistics of the large number of tanks, wells and other diversions are not available. The area under minor schemes in 1968–69 was of the order of 0.74 million hectares. Assuming an overall delta of 0.915 m., the approximate annual diversion may be of the order of 6,784 m. cu. m. Of this figure, ground water exploitation (wells & tubewells), accounts for nearly 5,562 m. cu. m.

Reservoir Losses

1.33 Data on reservoir losses for the major and medium schemes in the Chambal basin is not available. To make an approximate estimate of these losses, the Commission has assumed that they would be of the order of 20 per cent of annual diversion under these projects. On this basis, the reservoir losses work out to 987 m. cu. m.

For minor schemes, in the absence of observed statistics, it is extremely difficult to estimate the evaporation losses in the tanks. Assuming that the water spread of a tank would be about 87.5 per cent of the area irrigated from it, as estimated in the Krishna & Godavari basins* and that a total loss of 1.07 m. over the water surface area for the period that the tank is full (from June to December each year), the total reservoir losses from tanks in the basin would work out approximately 1,162 m.cu.m.

1.34 Thus, the major, medium and minor schemes in operation and construction in the basin in 1968–69 would use on completion and full development 13,867 m. cu. m., as detailed on page 23.

Of this, 5,562 m. cu. m. is expected to be from ground water resources (wells and tubewells) and 8,305 m. cu. m. from surface water resources.

With the construction of the Chambal Project and with the availability of electricity, a number of industries using Chambal waters have come up, particularly in and around Kota City. The Atomic Reactor at Rana Pratap Sagar will also draw water from the Chambal river. Data on the

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*Report of the Krishna-Godavari Commission (July, 1962).

	m. cu. m.
Annual diversion under major & medium schemes	4,934
Annual diversion under minor schemes	6,784
Reservoir losses under major & medium schemes	987
Reservoir losses under minor schemes (tanks)	1,162
Total utilisation	13,867

needs of all these industries is not readily available. With the expansion of industrialisation, the needs of water for industries is bound to increase.

FUTURE DEVELOPMENT

1.35 As stated in paragraph 1.22 the average annual yield of the Chambal basin is estimated at 24,312 m. cu. m. and the surface water utilisation from all projects so far completed under construction (para 1.34) can be put at 8,305 m. cu. m. A balance of nearly 16,007 m. cu. m. of water would be still available in the basin for future projects.

During the Fourth Five Year Plan, neither Madhya Pradesh nor Rajasthan has included any new major scheme in the Chambal basin, their efforts being concentrated on completing the Chambal Project during the Plan period. Irrigation from minor sources is expected to increase by 159,220 hectares during the Fourth Plan period, utilising about 1,705 m. cu. m. (inclusive of tank losses). The following new storage works have been contemplated.

Parvati Project benefiting		80,000	hectares
Kakunda dam	„	91,000	„
Ranjitpura dam	„	27,200	„
Kumri dam	„	22,400	„
Mana dam	„	47,600	„
Silolgarh dam and Rajgarh weir	„	25,600	„
Rajpura weir	„	73,200	„
Total		367,000	hectares

All the above are major projects. No information is available regarding the possible future medium and minor schemes in the basin. Assuming that an area, equal to the area under major projects, is likely to be brought under irrigation by medium and minor schemes, the total area which is likely to be provided with irrigation will be of the order of 0.734 million hectares.

1.36 The annual utilisation, assuming a uniform delta of 0.91 m. will be 6,661 m. cu. m. Allowing for reservoir and other losses, the future utilisation can be of the order of 8,634 m. cu. m. On completion and full development of all future projects, about 24,206 m. cu. m. of water (14,422 m. cu. m. of surface and 9,784 m. cu. m. of ground) would have been utilised.

FLOODS, WATERLOGGING AND DRAINAGE

1.37 There is practically no flood problem in the Chambal basin.

1.38 With the advent of canal irrigation in the Chambal Project command, it has been observed that the sub-soil water level has been steadily rising. Canal irrigation started in 1960 and with 5 years of irrigation, an area of approximately 16,400 hectares in Rajasthan has been damaged due to waterlogging. The area damaged had increased to 40,700 hectares by 1969. In Madhya Pradesh too, the situation is no better. The Geological Survey of India has demarcated an area of nearly 0.11 million hectares as liable to be affected by waterlogging.

1.39 The Study Group on Irrigation and Power of the National Planning Council in the Planning Commission in their report of August, 1967 on the Chambal Project suggested the following remedies:

(a) Removing of obstructions in all natural drainage channels and their notification so that all future obstructions to flow therein can be prevented.

(b) A careful watch be maintained on the behaviour of the sub-soil water table by regular observations, twice a year in October and June, of the depth of sub-soil water below the surface. For this purpose, wells (preferably village drinking water wells) suitably spaced preferably along cross section lines, should be selected.

(c) Funds should be made available, on a priority basis, for the construction of seepage drains to drain off all low-lying pockets, in the first instance. If such pockets can be drained effectively, the relatively high areas may not need any drainage measures. Shallow-field-drains along the margins of fields (as are at present being constructed in some places by the Agriculture Department) cannot serve any useful purpose.

(d) As far as possible, all irrigation channels should either run with a full supply or remain closed. This is necessary not only for economy in the use of water and equitable distribution but also as an anti-waterlogging measure.

(e) Contour maps, in the scale of one inch to a mile should be prepared for the entire command on which all natural drainage channels should be marked. These maps are necessary for planning artificial drainage.

(f) Geological investigations should be made in the river above the Kota barrage to locate any faults in the bed-rock through which water from the pond above the Kota barrage might be seeping into the command area along the upper reaches of the two canals.

(g) All borrow pits along irrigation channels (and along roads etc.), which have standing water, should be drained by parallel shallow drains into the nearest natural drainage. The shallow drains along irrigation channels should be constructed at some distance from the toe of the bank, about 300 m. in the case of main canals and, say, 150 m. in the case of smaller channels. If necessary, short cross drains can be made to lead water from the toe of the bank of the main canals to the parallel drains, particularly where the Right Main Canal passes through old tanks and there is a large accumulation of standing water.

SOIL CONSERVATION

1.40 The problem of soil erosion is very acute in the basin. In the districts of Shivpuri, Ujjain and Mandsaur extensive gullies have been formed along the river banks. Gullied lands are extensive along the Chambal itself. Soil erosion in the basin seems to be aggravated due to over-grazing of the hill slopes and the woodlands especially by huge herds of goats. Some accelerated erosion is also observed where cultivation is extended to hill slopes.

1.41 The problem is no less severe in Rajasthan. The survey of the Chambal Project area in the Kota and Bundi districts which was conducted in 1950 indicated that 10% of the area suffered from sheet erosion and 23% was affected by ravines and gullies. Nearly 21 per cent of the command area is unproductive because good lands have been reduced to ravines. Erosion along the river banks is also extensive. The marginally cultivated lands close to various rivers and their tributaries estimated to be of the order of 3,400 sq. km. are in constant danger of being washed away.

1.42 In Madhya Pradesh the work of soil conservation is being done by two agencies. The Agricultural Department takes up measures like contour bunding etc. in the cultivated areas while the Forest Department takes up measures like afforestation.

A certain amount of soil conservation is being carried out by the Agricultural Department from 1957–58. It is stated that nearly 40,000 hectares of cultivated land was contour bunded during the Third Five Year Plan. Under a special programme sponsored by the Union Government, another 15,400 hectares were covered by contour bunding. All the work so far done has been in the districts of Ujjain, Indore and Dewas in the upper water shed of the Kshipra, the Kunu, the Gambheri and the Chambal, as these were considered to have a relatively larger soil erosion hazard. The Forest Department has covered an area of approximately 3,800 hectares as a part of the Central scheme. Below Gandhi Sagar also, an area of nearly 19,000 hectares was covered by the Forest Department during the Third Plan period as part of the State Plan for soil conservation.

1.43 A capacity survey of the Gandhi Sagar reservoir has been undertaken. The Central Water & Power Commission has conducted some studies on the siltation of this reservoir. The gross storage capacity of the reservoir is 7,722 m. cu. m. of which 6,892 m. cu. m. is the live storage. Only 84 per cent of the catchment area is being gauged as the balance of 16 per cent drains directly into the reservoir. The observations were started in 1962 and the details of silt trapped annually during the period 1962 to 1967 are given below.*

Sl. No.	Year	Silt load trapped (including 10% of suspended load taken as bed load) m. cu. m.
1.	1962	12.07
2.	1963	8.66
3.	1964	1.88
4.	1965	1.04
5.	1966	2.20
6.	1967	6.62
	Total	32.47

1.44 An analysis of the above data shows that the total silt load trapped in the reservoir, including the bed load, from 1962 to 1967, is of the order of 32.47 m. cu. m. i.e. 5.41 m. cu. m. on an average annually

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*Sedimentation data of selected reservoirs in India (revised edition), Central Water and Power Commission, March, 1969 (unpublished).

This works out to 0.024 m. cu. m. per 100 sq. km. of the catchment area against the annual rate of siltation of 0.036 m. cu. m. per 100 sq. km. assumed in the project estimates.

1.45 The rate at which the siltage is taking place in the reservoir is lower than the rate of siltation assumed in the project estimates. It may, however, be pointed out that the direct draining area is very severely eroded and the contribution of silt from this area will be higher for each sq. km. as compared to the remaining catchment area.

SALIENT FEATURES OF THE YAMUNA BASIN
(Excluding the Chambal Sub-Basin)

(i) Source: Near Bandarpunch in the Tehri-Garhwal district of Uttar Pradesh (Latitude 30°58′N, Longitude 78°27′E).

(ii) Length: Uttar Pradesh	970 km.	602 miles
Common boundary between Himachal Pradesh and Uttar Pradesh	30 km.	19 miles
Common boundary between Haryana and Uttar Pradesh	328 km.	204 miles
Delhi	48 km.	30 miles
Total	1,376 km.	855 miles

(iii) Drainage area	Sq. km.	Sq. miles
Himachal Pradesh	4,317	1,667
Haryana	34,283	13,237
Punjab	58	22
Uttar Pradesh	73,763	28,480
Madhya Pradesh	81,030	31,286
Rajasthan	31,820	12,285
Delhi	1,484	573
Total	226,755	87,550

(iv) Population (1971 Census):	45.66 millions.	
(v) Density of population:	201 per sq. km.	521 per sq. mile
(vi) Average annual run off	65,621 m.cu.m.	58.20 MAF

	Thousand hectares	Thousand acres
(vii) Culturable area (1967-68)	16,777	41,458
(viii) Net area sown (1967-68)	13,051	32,250
(ix) Gross area sown (1967-68)	16,400	40,526
(x) Net area irrigated (1967-68)	3,055	7,549
(xi) Gross area irrigated (1967-68)	3,871	9,566
(xii) Ultimate irrigation by major and medium projects under operation and construction in 1968-69	1,863	4,604

		m.cu.m.	MAF
(xiii) Water utilisation, including reservoir losses on completion and full development from major, medium & minor projects under operation and construction 1968-69	Surface Water	15,523	12.58
	Ground Water	9,513	7.71
	Total	25,036	20.29

CHAPTER II

THE YAMUNA BASIN (EXCLUDING THE CHAMBAL BASIN)

The Basin

The Yamuna basin (excluding the Chambal Sub-Basin) extends over an area of 226,755 sq km. and lies between east longitudes 75°8′ to 81°50′ and north latitudes 22°54′ to 31°25′. Lying between the Himalayas in the north and the Vindhyas in the south, the basin covers large areas in the States of Haryana, Uttar Pradesh, Madhya Pradesh and Rajasthan and small areas in Himachal Pradesh, Punjab and the Union Territory of Delhi. The State-wise distribution of the drainage basin of the river is give below:

Himachal Pradesh	4,317	sq. km.
Haryana	34,283	,,
Punjab	58	,,
Uttar Pradesh	73,763	,,
Madhya Pradesh	81,030	,,
Rajasthan	31,820	,,
Delhi	1,484	,,
Total	226,755	sq. km.

2.2 The basin is bounded on the north by the Himalayas, on the east by the ridge separating it from the basin of the main Ganga river, on the south by the Vindhya range and on the west by the ridge separating it from the Luni and the Ghaggar Basins. The basin is of irregular shape with a maximum length of 667 km. in the north west-southeast direction and a maximum width of 492 km. in the north-east south-west direction.

THE RIVER SYSTEM

2.3 The Yamuna river rises in the Tehri Garhwal district of Uttar

Pradesh from the Yamnotri glacier near Bandarpunch at an elevation of about 6,320 m. at north latitude 30°58′ and east longitude 78°27′. The Rishiganga a tributary of the Yamuna rises 3 km. further north-west and joins the Yamnotri stream on its right bank near Banas while two other streams, the Unta and the Hanumanganga rising from the Jakhal glacier and the Chhaian Barmak glacier respectively to the south of Bandarpunch meet the main stream on its left bank. Further south-west the Yamuna receives several tributaries from the lesser Himalayan ranges and ridges.

2.4 The Tons, the largest Himalayan tributary of the Yamuna, rises from the north-eastern slope of Bandarpunch at an elevation of 3,900 m. at north latitude 31°13′ and east longitude 78°26′ and flowing in a valley north-west of the Yamuna, meets it below Kalsi on the south-west fringe of the Mussorie range. At the confluence of the two rivers, the Tons carries almost twice the volume of waters as the Yamuna and is considered as the principal source of that river. Another important tributary, the Giri rises further north-west of the Tons draining areas in Himachal Pradesh.

2.5 The combined stream of the Yamuna and the Tons then forces its way through the Siwalik range of hills and debouches into the plains of Uttar Pradesh in the Saharanpur district. When the river emerges from the hills, its waters have already been tapped for irrigation at the Tajewala head-works from where two important canals, namely, the Western Yamuna and the Eastern Yamuna, take off to irrigate vast areas in Haryana and Uttar Pradesh. From Faizabad, the river flows for a distance of 104 km. in a south-westerly direction and receives the Maskara stream on its left bank. Near Bidauli in the Muzaffarnagar district (Uttar Pradesh) it turns due south for a distance of 128 km. to reach Delhi. The Agra Canal takes off from the river at Delhi from the Okhla headworks to irrigate areas in Uttar Pradesh. The Gurgaon Canal, which is under construction, will take off from the Agra Canal to irrigate lands in Haryana and Rajasthan. Beyond Delhi, the Yamuna continues to flow south as far as Mathura, a distance of 203 km. The Hindon river joins the Yamuna on its left bank at Dankaur.

2.6 From Mathura onwards the river flows in a south-easterly direction through the Agra, Mainpuri, Etah, Kanpur and Allahabad districts before joining the Ganga near Allahabad City. During its course through these districts it is joined by some small tributaries, namely the Karon, the Sangar and the Rind on its left bank and by the Chambal, the Sindh, the Betwa and the Ken on its right bank. All the right bank tributaries have their origins in the Vindhyas.

2.7 The total length of the Yamuna from its source at Yamnotri to its confluence with the Ganga near Allahabad is about 1,376 km., of which 970 km. are in Uttar Pradesh, 30 km. form the common boundary between Himachal Pradesh and Uttar Pradesh, 328 km. form the common boundary between Haryana and Uttar Pradesh and the balance of 48 km. are in the Union Territory of Delhi. The river is usually confined within well-defined banks. Historically important places like Delhi and Agra and holy places like Mathura and Allahabad are situated on its banks.

2.8 The most important tributary of the Yamuna is the Chambal, which has been dealt with separately. The other tributaries are the Hindon, the Sindh, the Betwa, the Dhasan and the Ken. Except the Hindon, all the other important tributaries of the Yamuna including the Chambal join the main river on its right bank. The following paragraphs describe briefly the important tributaries:

2.9 *The Hindon* river rises on the southern slopes of the Siwaliks in the Saharanpur district of Uttar Pradesh. In its course of 256 km., it drains part of the Saharanpur, Muzaffarnagar and Meerut districts and ultimately joins the Yamuna from the left, downstream of the Okhla weir. A part of its channel acts as a link between the Yamuna and the Upper Ganga Canal.

2.10 *The Sindh* is one of the longest rivers of the Central India to join the Yamuna on its right bank. It rises in a tank 543 m. above sea level near a village in the Vidisha district of Madhya Pradesh. It drains a number of districts in Madhya Pradesh and flows generally in a north-eastern direction for a length of nearly 415 km. and drains an area of 25,085 sq. km. before joining the Yamuna in Uttar Pradesh, slightly downstream of the confluence of the Chambal with the Yamuna. The river receives a number of tributaries, the more important of them being the Parvati and the Kunwari on its left bank and the Pahuj on its right.

2.11 *The Betwa* rises in the Bhopal district of Madhya Pradesh at an elevation of about 475 m. above mean sea level. After flowing in a generally north-eastern direction through Madhya Pradesh, it enters the Jhansi district of Uttar Pradesh. It joins the Yamuna near Hamirpur after flowing for a length of about 300 km. in Uttar Pradesh. The total catchment area of the basin is 46,580 sq. km. One of the important tributaries of the Betwa is the Dhasan.

2.12 *The Ken* has its origin on the north-west slopes of the Kaimur hills in the Satna district of Madhya Pradesh. It flows in a generally north-easterly direction and joins the Yamuna near Chilla after flowing for a length of 360 km. and draining an area of 28,224 sq. km.

2.13 Other minor streams which neither flow into the sea nor into any major river but are simply absorbed by the sandy tract in which they flow, are the Chautang, the Sahibi, the Dohan, the Kantli, the Bahah and the Banganga.

CLIMATE

2.14 In the northern region of the basin, the Himalaya exercises a dominating influence on climate. Regions situated close to the Himalayan ranges have a moderate climate. In the plains, the climate is extreme intense heat in summer and intense cold in winter. The summer temperature in the plains is around 45°C while in winter the minimum temperature occasionally touches freezing point.

2.15 The physiographical and geological features of the upper basin which lies in the Himalayan range accounts for most of the runoff in the river. This region on an average receives a rainfall of 1,500 mm. The plains receive rainfall varying from 1,500 mm. to 400 mm. Rainfall decreases on the right bank towards Rajasthan. The entire basin comes under the influence of the south-west monsoon and the major part of the annual rainfall is received between June and September. Winter rainfall though small in quantity, is received during the months from December to February. The average annual and monsoon rainfalls in various districts lying in the basin are given below:

Table 2.1

Monsoon and Annual Rainfall—Yamuna Basin

District	Average Annual rainfall (mm.)	Monsoon rainfall (mm.)
1	2	3
Himachal Pradesh		
Sirmur	N.A.	N.A.
Mahasu	N.A.	N.A.
Simla	1,528	1,161

Table 2.1—Contd.

1	2	3
Haryana		
Ambala	893	717
Gurgaon	531	455
Karnal	569	507
Rohtak	458	381
Hissar	375	303
Mohindragarh	N.A.	N.A.
Sangrur	508	422
Uttar Pradesh		
Agra	656	584
Allahabad	976	865
Aligarh	663	580
Bulandshar	674	582
Banda	946	851
Kanpur	802	713
Dehradun	2,142	1,849
Etah	695	612
Etawah	752	669
Fatehpur	904	806
Farukhabad	793	703
Hamirpur	851	769
Jalaun	783	705
Jhansi	879	797
Mainpuri	715	631
Meerut	720	599
Mathura	593	521
Muzaffarnagar	759	640
Saharanpur	949	789
Tehri garhwal	1,449	N.A.
Delhi		
Delhi	467	408
Madhya Pradesh		
Chhatarpur	1,075	977
Panna	1,176	1,060
Datia	740	671
Satna	1,000	967
Tikamgarh	1,001	897
Bhopal (Sehore)	1,245	1,153
Sagar	1,235	1,113

Table 2.1—Contd.

1	2	3
Bhind	668	615
Vidisha	1,134	1,039
Gird (Gwalior)	751	690
Guna	1,054	967
Shivpuri	816	755
Morena	720	665
Jabbalpur	1,274	1,131
Damoh	1,225	1,103
Rajasthan		
Alwar	612	535
Bharatpur	672	603
Jaipur	548	493
Jhunjhunu	445	381
Sawai Madhopur	689	635
Sikar	466	410
Churu	326	280
Ganganagar	254	209

Source: India Meteorological Department—Monthly & Annual Normals of Rainfall and of rainy days (1901 to 1950).

2.16 There are 219 rain-gauge stations in the Yamuna basin—128 up to the confluence of the Chambal with the Yamuna and 91 from the confluence of the Chambal to its confluence with the Ganga. This gives an average dispersion of one rain-gauge for every 1,014 sq. km. The distribution of the stations is uneven and their number is also not sufficient. It is suggested that more rain-gauges to obtain a balanced distribution over the entire basin should be established.

2.17 One departmental and two agro-meteorological observatories of the India Meteorological Department lie within the basin.* The departmental observatory is located at New Delhi and the agro-meteorological observatories are at New Delhi and Agra.

SOILS

2.18 No detailed soil survey of the basin has yet been made. However, the general data regarding the soils of India indicates that mainly alluvial, medium black, red sandy and mixed red and black soils occur in the basin. The principal soil types found in the various districts lying in the basin are given below:*

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*Evaporation Data (India), India Meteorological Department (April, 1970).

Table 2.2

Soils of Yamuna Basin

District	Type of soil
1	2
Himachal Pradesh	
Sirmur	Alluvial and brown hill
Mahasu	Brown hill
Simla	Brown hill
Haryana	
Ambala	Alluvial
Gurgaon	Alluvial and chestnut brown
Karnal	Alluvial
Rohtak	Alluvial and chestnut brown
Hissar	Chestnut brown and desert
Mahendragarh	Chestnut brown
Punjab	
Sangrur	Alluvial and chestnut brown
Uttar Pradesh	
Agra	Medium black and Alluvial
Allahabad	Red and yellow and Alluvial
Aligarh	Alluvial and saline
Banda	Alluvial and mixed red and black
Bulandshahr	Alluvial and saline
Kanpur	Alluvial and saline
Dehradun	Brown hill
Etah	Alluvial and saline
Etawah	Alluvial and saline
Fatehpur	Alluvial and saline
Farrukhabad	Alluvial
Hamirpur	Mixed red and black
Jalaun	Red sandy
Jhansi	Medium black and mixed red and black
Mainpuri	Alluvial
Meerut	Alluvial and saline
Mathura	Alluvial and saline
Muzaffarnagar	Alluvial

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*Indian Crop Calendar, Ministry of Food, Agriculture, Community Development and Cooperation (1967).

Table 2.2—Contd.

1	2
Saharanpur	Brown hill
Tehri Garhwal	Brown hill and submontane
Delhi	
Delhi	Alluvial
Madhya Pradesh	
Chhatarpur	Mixed red and black
Datia	Medium black and mixed red and black
Panna	Mixed red and black
Satna	Mixed red and black
Tikamgarh	Mixed red and black
Bhopal (Sehore & Raisen)	Medium and deep black
Sagar	Medium black
Bhind	Medium black
Vidisha	Medium black
Gwalior	Medium black and mixed red and black
Guna	Medium black and mixed red and black
Shivpuri	Medium black and mixed red and black
Morena	Medium black
Jabbalpur	Medium and deep black and skeletal
Damoh	Deep black and mixed red and black
Rajasthan	
Alwar	Alluvial
Bharatpur	Red and yellow, medium black and alluvial
Jaipur	Alluvial
Jhunjhunu	Grey brown, desert and chestnut brown
Sawai Madhopur	Red and yellow and medium black
Sikar	Alluvial, grey brown and desert
Churu	Desert
Ganganagar	Chestnut brown and desert

LAND USE & AGRICULTURAL PRACTICES

2.19 Land use details in the Yamuna basin for the year 1967-68 are given in Table 2.3.

2.20 Except in the head reaches of the river Yamuna lying in Himachal Pradesh and its south bank tributaries emanating from the Vindhyas in Madhya Pradesh, the entire basin lies in the Gangetic plain. Hardly 11.5 per cent of the total area of the basin is under forests. In Himachal

Table 2.3

Land Use Details—Yamuna Basin

(Thousand hectares)

Item	States						
	Himachal Pradesh	Haryana & Punjab	Uttar Pradesh	Delhi	Madhya Pradesh	Rajasthan	Total
1	2	3	4	5	6	7	8
Geographical area	432	3,434	7,376	148	8,103	3,182	22,675
Reporting area	236	3,421	7,327	148	8,066	3,111	22,309
Area under forests	38	52	676	3	1,662	144	2,575
Area not available for cultivation	19	363	977	43	1,060	495	2,959
Culturable area	179	3,006	5,674	102	5,344	1,272	16,777
Uncultivated culturable area	122	241	1,009	20	1,856	478	3,726
Net area sown	57	2,765	4,665	82	3,488	1,994	13,051
Area sown more than once	30	1,328	1,248	34	235	474	3,349
Total cropped area	87	4,093	5,913	116	3,723	2,468	16,400
Net irrigated area	6	883	1,536	25	293	312	3,055
Gross irrigated area	9	1,382	1,797	31	301	351	3,871
Percentage of net area sown to culturable area	31.8	92.0	82.2	80.3	65.3	80.7	77.8
Percentage of net irrigated area to net area sown	10.5	31.9	32.9	30.9	8.4	15.7	23.4

Pradesh, however, the area under forests constitutes nearly 16.1 per cent of the area of that State; Madhya Pradesh has 20.6 per cent of the area in the basin under forests. Nearly 75 per cent of the total area being culturable, the Yamuna basin is one of the important agricultural tracts in the Ganga basin. 77.8 per cent of the culturable area is cultivated annually —Haryana with 92 per cent of the culturable area cultivated ranks highest while Himachal Pradesh with 31.8 per cent is the lowest.

2.21 Irrigation has been practised in the basin for centuries. Important works like the Western and Eastern Yamuna Canals and Agra Canal, irrigating extensive areas, have existed in the basin for a very long time. During the Plan periods also, many big and small projects have been completed. Because of these works more than 23 per cent of the area cultivated annually is provided with irrigation facilities. Haryana, with 32 per cent and Madhya Pradesh with 8.4 per cent of their areas under irrigation, rank the highest and lowest in the basin respectively.

2.22 As in other parts of the country, agriculture in the Yamuna basin is dominated by food crops. An Average of 85–90 per cent of the cultivated area grows food crops. Important among the food crops are wheat, pulses, rice and other cereals like bajra, jowar and maize.

2.23 The crop pattern under irrigated conditions is more or less the same though the area under paddy has gone up at the expense of inferior cereals. Wheat, however, remains the most important crop. The area under sugarcane is also considerable.

Crop Seasons

2.24 The main crop seasons are kharif and rabi. The kharif season begins with the onset of the south-west monsoon in June and extends up to October. The rabi season lasts from November to March-April. Rice is the main kharif crop. Other cereals are jowar, bajra and maize. Wheat and barley are the most important rabi crops.

REGIONAL ECONOMY

Population

2.25 On the basis of the 1971 Census* and the percentages of the area of each district within the basin to the district as a whole, the total population in the basin is about 45.66 millions. The State-wise distribution is gven below:

Himachal Pradesh	0.31	millions
Haryana & Punjab	7.84	„
Uttar Pradesh	20.80	„
Delhi	4.04	„

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*Census Paper 1 of 1971 (Supplementary), Registrar-General (India).

Madhya Pradesh	7.80	millions
Rajasthan	4.87	„
Total	45.66	„

There are nine cities in the basin which have a population of more than one lakh each. The country's capital city (Delhi) lies within the basin. Other major cities are Agra, Mathura, Aligarh, Meerut, Saharanpur Jhansi in Uttar Pradesh and Sagar and Gwalior in Madhya Pradesh. Allahabad is situated at the confluence of the Yamuna and the Ganga. The density of population is the highest in Uttar Pradesh, most of which lies in the Gangetic plains. The lowest density is in Himachal Pradesh. The most densely populated district is Meerut (566 persons per sq. km.) and the least populated is Kinnaur (8 persons per sq. km.) in Himachal Pradesh.

2.26 With many big cities and towns and a large number of industries, the proportion of the rural population is lower than in most parts of India. Of the total population in the basin, nearly 84.6 per cent live in rural areas and the remaining 15.4 per cent in urban areas. The corresponding figures for India as a whole are 80.1 per cent and 19.9 per cent respectively. The working force constitutes nearly 32.8 per cent, of which 54.2 per cent is engaged as cultivators and 19.0 per cent as agricultural labourers. The remaining 26.8 per cent of the working force is engaged in industries and other tertiary activities.

Forests & Agriculture

2.27 Except in Himachal Pradesh, the southern-districts of Uttar Pradesh and parts of Madhya Pradesh, the entire basin lies in the Gangetic plain and is flat and culturable. Forests occupy only 11.5 per cent of the total area of the basin (percentages of forest land in Himachal Pradesh and Madhya Pradesh are 16.1 and 20.6 respectively) and the culturable area constitutes 75.2 per cent. Out of a total culturable area of 16.78 million hectares, more than three-fourths of it, i.e. 13.05 million hectares are annually cultivated. A characteristic feature of agriculture in the basin—particularly in Haryana and Uttar Prdesh—is the high percentage of area under irrigation. On an average, 23.4 per cent of the total cropped area has irrigation facilities. The percentage of area irrigated in Haryana and Uttar Pradesh areas is as high as 32 and 33 respectively while it is the lowest at 8.4 in Madhya Pradesh. Wheat is the most important irrigated crop in the basin. Nearly 37.8 per cent of the irrigated area is under wheat.

Power

2.28 The Central Water & Power Commission has assessed the total hydro potential in the Yamuna basin as 1,004 MW at 60 per cent load factor. The present hydro-power development (including projects under construction) in the basin is given below:

Table 2.4

Hydro-Power Projects—Yamuna Basin

State/Project	Installed capacity (MW)
1	2
Himachal Pradesh	
(i) Baira Siul	201.00
Haryana	Nil.
Uttar Pradesh	
(i) Matatila	30.00
(ii) Yamuna H.E. Scheme:	
Stage I	84.75
Stage II	360.00
Stage III	30.00
Delhi	Nil
Madhya Pradesh	Nil
Rajasthan	Nil
Total	705.75 MW

In addition to the development of hydroelectric power the production of thermal power in the basin is considerable. There are a number of thermal stations to satisfy the increasing demand for power. The details of the thermal stations are given in Table 2.5.

Areas of Haryana and Delhi in the basin also get power from the Bhakra Project in the Indus basin.

Mineral Wealth

2.29 The mineral wealth of Yamuna basin is poor. Except for some

Table 2.5

Thermal Power Projects—Yamuna Basin

State/Thermal Station	Installed capacity (MW)
1	2
Haryana	
Faridabad Station—	
Stages I & II	70
Uttar Pradesh	
Harduaganj (near Aligarh)—	
Stages I to IV	420
Delhi	
Rajghat	55
Indraprastha	279
Badarpur	300

districts in Rajasthan and Madhya Pradesh where there are mineral deposits, the rest of the basin lying in the Gangetic plain is practically devoid of any important minerals. The important minerals found in the various States within the basin area.*

Lime stone: In the Sirmur, Ambala, Mahendragarh, Rohtak, Hissar, Dehradun, Tehri Garhwal, Banda, Satna and Morena districts.

Irone ore: In the Mahendragarh and Gwalior districts.

Copper ore: In the Mahendragarh, Jhunjhunu and Alwar districts.

State: In the Mahendragarh and Gurgaon districts.

Asbestos: In the Mahendragarh district.

Barytes: In the Mahendragarh, Alwar and Bharatpur districts.

Baryl: In the Mahendragarh district.

Calcite: In the Mahendragarh district.

Feldspar: In the Mahendragarh district.

Manganese ore: In the Mahendragarh district.

Pyrophylite: In the Hamirpur and Jhansi districts.

China Clay: In the Gurgaon, Gwalior, Shivpuri and Satna districts.

Fire clay: In the Gwalior, Shivpuri and Satna districts.

Sand stone: In the Morena district.

Industrial diamonds: In the Panna district.

Talc: In the Jaipur and Sawai Madhopur districts.

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*Techno-Economic Surveys of Madhya Pradesh, Panjab, Rajasthan and Uttar Pradesh, NCAER.

Industries

2.30 The important industries in the basin are given below:

Woollen textiles: In Allahabad and Mahasu.

Cotton textiles: In Saharanpur, Modinagar, Delhi, Hathras, Agra, Dehradun, Allahabad and Aligarh.

Silk and other fabrics: In Saharanpur, Delhi, Agra and Gwalior.

Tobacco products: In Delhi and Saharanpur.

Vegetable oils: In Jagadhri, Delhi, Ghaziabad, Karnal and Rohtak.

Leather and leather goods: In Aligarh, Agra and Allahabad.

Rubber and rubber goods: In Meerut and Delhi.

Plastic and allied products: In Delhi and Gwalior.

Sports goods: In Meerut, Delhi, Agra, Allahabad, and Gwalior.

Paper, Cardboard and Newsprint: In Jagadhri, Saharanpur, Meerut, Delhi, Mathura, Allahabad and Kalpi.

Glass and Ceramics: In Delhi, Meerut, Firozabad, Allahabad, Agra, Aligarh, Kalpi, Gwalior, Faridabad and Sonepat.

Power alcohol: In Meerut.

Essential oils: In Saharanpur, Delhi and Meerut.

Automobiles: In Faridabad.

Automobile parts: In Gurgaon, Faridabad, Ballabgarh and Agra.

Bicycle parts: In Allahabad, Faridabad and Ballabgarh.

Machine tools: In Meerut, Agra, Faridabad, Ballabgarh.

Electric equipment and Appliances: In Meerut, Faridabad, Ballabgarh, Agra, Allahabad and Aligarh.

Bicycles: In Sonepat, Delhi, Gurgaon, Faridabad, Ballabgarh and Agra.

Sugar: In Jagadhri, Saharanpur, Rohtak, Karnal, Delhi, Meerut, Ghaziabad, Muzaffarnagar and Gwalior.

Radio and Electronics: In Saharanpur, Meerut and Delhi.

Agricultural equipment: In Saharanpur, Karnal, Meerut, Mathura, Agra, Gwalior, Lashkar, Jhansi, Faridabad, Ballabgarh and Allahabad.

Wires and Cables: In Karnal, Meerut and Delhi.

Copper and Brass: In Jagadhri, Panipat, Rewari, Agra and Hathras.

Metal tubes and Conduits: In Panipat, Delhi and Allahabad.

Machinery: In Delhi, Aligarh, Agra and Gwalior.

Machine parts: In Panipat, Delhi and Agra.

Chemicals (Acids, Caustics): In Jagadhr, Delhi, Ghaziabad, Alwar and Agra.

Inks, Paints and Varnishes: In Delhi, Alwar, Agra, Ghaziabad, Gwalior and Allahabad.

D.D.T. and Insecticides: In Delhi and Agra.

Soaps: In Delhi, Agra and Allahabad.

Drugs and Pharmaceuticals: In Jagadhri, Delhi, Mathura, Alwar, Agra, Gwalior, Jhansi, Allahabad and Saharanpur.

Cement: In Mohendragarh and Kymore.

Asbestos Cement: In Ballabgarh and Kymore.

Hume pipe: In Gurgaon and Rohtak.

Rice milling and Wheat Flour milling: In Karnal and Rohtak.

China and Earthen ware: In Ghaziabad Sirmur.

Communications

2.31 The basin is well served by both railways and roads except in the hilly regions of Himachal Pradesh and Madhya Pradesh. The broad-gauge railway lines from Delhi to Madras, Delhi to Kalka, Delhi to Bombay (both on the Western and the Central Railway), and Delhi to Howrah all pass through the basin. In addition, the metre-gauge line from Delhi to Ahmadabad also passes through the basin. There are a number of National Highways in the region. Many State and district highways cris-crossing the basin connect practically all the important cities and towns.

Within the basin, districts in the interior of Madhya Pradesh are not well served with communications. The same is the case with Himachal Pradesh.

The Yamuna in the plains is navigable right up to its confluence with the Ganga at Allahabad.* Small boats are used for ferrying people and small loads across the river. The tributaries are not navigable.

WATER RESOURCES

Surface Water

2.32 The surface water potential of the Yamuna river system had been assessed at different times by different authorities. The very first assessment was made by the First Irrigation Commission. On the basis of the gauge and discharge data available for the Ganga, the Commission assessed the surface flow of the Ganga above Benaras (Varanasi) to be 1,69,902 m. cu. m.** In 1949 on the basis of Khosla's formula, the annual runoff of the Yamuna (excluding the Chambal) was estimated at 64,782 m. cu. m.† In 1960, when the irrigation potential studies of the country were made by the Central Water and Power Commission, the total annual runoff of the Yamuna river system was assessed to be 65,621 m. cu. m.*

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*Report Navigable Waterways of India, Central Water and Power Commission (1961).

**Report of the Indian Irrigation Commission (1901-03).

†An appraisal of water resources by Dr. A.N. Khosla, UNESCN.

2.33 Systematic gauge-discharge observation sites have been established on the main Ganga and its tributaries since 1958. Prior to this, though some observations on some of the important rivers in the basin had been carried out by the States concerned, they were neither systematic nor regular.

Ground Water

2.34 The Geological Survey of India has conducted ground water studies in different districts of the States in the Yamuna basin. The following paragraphs describe the position of ground water resources in these districts.†

2.35 In Himachal Pradesh the hydrological studies carried out in the Simla district generally indicate the possibilities of promising aquifers within a depth of 100 m. In Sirmur district an area of about 400 sq. km. has been covered in the Paonta valley. Ground water in the valley occurs both under water-table and confined conditions, and is suitable for irrigation purposes. In Haryana the area in the Gurgaon district is underlain by the rocks of the Aravalli and Delhi systems and by quarternary alluvium. The depth to water in the area varies widely, from less than two metres to more than 20 m. below the land surface. Rohtak district is underlain by alluvium deposits of quarternary age. The development of ground water through tubewells on a moderate scale appears to be feasible in some parts of the district. Except for small area around near Sasot, the Mahendragarh district does not hold promise for ground water development through tubewells. Ground water in the Karnal district occurs both under unconfined and confined conditions. The depth to water is 10 m. below the land surface. The water table lies at very shallow depth in canal command areas and some areas are even waterlogged. In the Hissar district, shallow ground water occurs under unconfined conditions. In the vicinity of canals, the water table is fairly high.

2.36 In the Union territory of Delhi, ground water in the areas occurs both under water-table and confined conditions. Sand and Kankar generally form the principal aquifers. The water-table generally lies within 4 m. of the land surface except in the vicinity of the ridge where the water levels are comparatively lower. The water-table to the east of the ridge slopes towards the Yamuna river while the water-table to the west of the ridge slopes towards the Najafgarh Jheel. The ground water in the areas to the west of the ridge is often saline except in the vicinity of canal distributaries.

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*Report of the technological possibilities of irrigation projects in India, Central Water and Power Commission (Unpublished).

†Ground Water Resources of India, Status and Surveys, Prospects and Perspectives, Geological Survey of India (August 1970).

2.37 The area between the Utangan, Chambal and Yamuna rivers lying in the Agra and Mathura districts of Uttar Pradesh is by and large suitable for the construction of tubewells to a depth of about 100 m. In the northern parts of Agra district, the ground water is generally of poor chemical quality. Ground water in the Aligarh district occurs both in confined and non-confined conditions. In the Allahabad district, ground water occurs in both the alluvium and hard rock. The near surface ground water occurs under water-table conditions while the deeper ground water occurs under confined conditions. Ground water development by heavy duty tubewells is considered to be feasible in the entire alluvium tract. Ground water in the Doon valley and Farrukhabad district occurs both under water-table and confined conditions. In the Etah and Etawah districts, ground water occurs under confined and unconfined conditions. Hamirpur district is occupied by Bundelkhand granite and alluvium. Geo-hydrological studies indicate that artesian conditions may be encountered around Hamirpur. In the Jalaun district the depth to water varies between 2 m. and 42 m. below the land surface. The water-table is generally low towards the Yamuna river. The major part of the district is considered to be suitable for moderate to heavy duty tubewells. Jhansi district is covered by Bundelkhand granite, Vindhyan rocks and alluvium. Yields from tubewells in the first two of the areas mentioned are not significant. However, in the alluvium tracts tubewells seem feasible particularly in the northern parts of the district. Kanpur district is underlain by quarternary alluvium. Near surface ground water in the district occurs under water-table conditions whereas in the deeper aquifers it occurs under confined conditions. The water-table is low near the Yamuna whereas along the banks of the major canals, it is high. Ground water is generally slightly alkaline. Ground water investigations carried out in the Mainpuri district show that the ground water, in general, is fresh and potable. The area holds promise for large-scale ground water development through heavy duty tubewells.

2.38 From the hydrological data collected in the Fatehpur district, it is observed that there is a ground water divide between the Ganga and the Yamuna catchment and that the Ganga catchment is more permeable than the Yamuna catchment. The yields in the Yamuna catchment are expected to be much less than in the Ganga sub-catchment.

2.39 In Rajasthan an area of 1,270 sq. km. has been surveyed by the Geological Survey of India in the Banganga sub-basin lying in the Bharatpur and Jaipur districts. The depth of the water-table is less than 10 m. in most parts of the area surveyed.

2.40 The data in the above paragraphs indicate that the areas of the basin lying in Haryana and Uttar Pradesh (except the Bundelkhand region) have good scope for the development of ground water resources. In the Bundelkhand region, ground water occurs in the fissures and joints of the rocks and is tapped by means of large diameter open wells. However, ground water development in the Bundelkhand region can only be on a modest scale.

Though there has been a large scale development of ground water resources by means of tubewells, in the alluvial plains of Haryana and Uttar Pradesh, no quantitative assessment of this resource is available.

EXISTING DEVELOPMENT

2.41 The waters of the Yamuna and its tributaries have long been used for the irrigation of vast areas in Haryana and Uttar Pradesh. Even prior to the First Five Year Plan, many large schemes existed in the basin. The Western and the Eastern Yamuna Canals taking off at Tajewala and the Agra Canal taking off at Okhla near Delhi are the most important works on the main river. On its tributaries like the Sindh, the Betwa and the Ken also, many schemes irrigating large areas have been in operation since the 19th century.

2.42 *Western Yamuna Canal*: Work on the Western Yamuna Canal was reportedly started in 1356 during the rule of Ferozeshah II, who utilised the bed of a torrent now known as Chautang to bring the waters of the Yamuna to the Royal gardens at Hissar and Hansi. This work was further modified and improved during the time of the Moghul kings, Akbar and Shahjehan and during the latter's rule, the canal was extended up to Delhi through Panipat and Sonepat. However the Western Yamuna Canal, as it exists today was taken up for construction in 1817 by G. R. Blance of the Bengal Engineers. The Western Yamuna Canal, as constructed by him, took off from the Yamuna near Hathnikuni and followed an old creek of the river until it joined the Pathrala and Somb torrents.

In the absence of a permanent headworks, the supplies fluctuated with seasonal changes in the river level.

In 1873, the remodelling of the entire canal system was taken up. A permanent weir across the river Yamuna at Tajewala and a low masonry dam at Dadupur about 19 km. below Tajewala were constructed in 1875-79 by John Colvin of the Bengal Engineers. Again, fifty years later, between 1940 and 1943, the canal was extensively remodelled and extended. The area irrigated annually under the Western Yamuna Canal prior to 1951 was 0.488 million hectares.

The work of further remodelling the Western Yamuna Canal system was again undertaken during the First and subsequent Plans to make use of the additional water available from storages on the Sutlej and the Beas (Indus Basin). The additional area irrigated annually under the present remodelling scheme is 0.248 million hectares. Thus the system as a whole provides irrigation for an area of 0.736 million hectares in Haryana State.

2.43 *Eastern Yamuna Canal*: The Eastern Yamuna Canal takes off from the Yamuna river on its left or eastern bank at a point not far from the head of the Western Yamuna Canal. It is believed to have been originally excavated in the reign of Mohammed Shah (1718-1748) but fell into disuse later, till it was renovated by the British in 1830. A permanent head regulator for the canal was constructed at Tajewala (between 1872-78) a little after the construction of the Tajewala headworks for the Western Yamuna Canal and the river supplies at the headworks were shared between the two canals in agreed proportions. The Eastern Yamuna Canal irrigates an area of 0.191 million hectares annually in the Saharanpur, Muzaffarnagar and Meerut districts of Uttar Pradesh.

2.44 *Agra Canal*: The Agra Canal also takes off from the Yamuna river at the Okhla weir near Delhi. The weir and the 160 km. long canal were constructed between the years 1868 and 1873. As the waters of the Yamuna are inadequate to irrigate the area commanded by the Agra Canal, they are supplemented by the waters of the Hindon river through the Hindon cut. During the non-monsoon period when the Hindon flow dwindles supplier in the Agra Canal are supplemented by the Ganga Canal via the Jani escape, the Hindon river and the Hindon cut. The Agra Canal provides irrigation to an area of 0.138 million hectares in the Agra and Mathura districts of Uttar Pradesh.

2.45 In addition to the above works, which were executed on the Yamuna river itself, there were also schemes on its tributaries. The more important of these were the Doon Canal (10,920 hectares), the Betwa Canal (98,700 hectares), the Dhasan Canal (24,280 hectares) and the Ken

Canal (75,260 hectares) providing irrigation in the districts of Dehradun, Jhansi, Hamirpur and Banda districts respectively of Uttar Pradesh.

2.46 During the Plan period, a number of schemes both big and small have been undertaken in the basin. The more important of the projects are the remodelling of the Western Yamuna Canal (Yamuna), the Gurgaon Canal (Yamuna), the Matatila Dam and the Bander Canal (Betwa). Some of the projects are described below:

2.47 *Matatila Project*: The project consists of an earthen dam across the river Betwa 56 km. south-west of Jhansi in Uttar Pradesh. The maximum height of the dam is 36.6 m. and its length 6,378 m. The reservoir has got a live storage capacity of 777 m. cu. m. (gross storage 1,135 m. cu. m.). The ultimate area to be irrigated under the project in Uttar Pradesh is 1,20,420 hectares. According to the agreement reached between Madhya Pradesh and Uttar Pradesh, the project has also to serve an area of 45,340 hectares in the Madhya Pradesh Ex-Bander Canal. The work on the project started in 1952 and all works in Uttar Pradesh have been completed in 1966. The work on the Bander Canal in Madhya Pradesh, however, is yet to be completed. The estimated cost of the project is Rs. 124.60 million.

2.48 *Remodelling of the Western Yamuna Canal*: The scheme envisages the remodelling of the Western Yamuna Canal System to increase irrigation to an additional area of 247,960 hectares in Haryana State. The project envisages the utilisation of water from the Beas on completion of the dam on that river. Work on the project started in 1951-52 and it is expected to be completed during the Fourth Plan period. The estimated cost of the project is Rs. 83.6 million.

2.49 *Gurgaon Canal*: The project envisages a canal taking off from the Agra Canal, 8 km. below Okhla near Delhi to extend irrigation to an area of 101,580 hectares in the Gurgaon district of Haryana State. The project also envisages the extension of irrigation to 25,090 hectares in Rajasthan.

2.50 The table 2.6 shows the salient features of all the projects in the basin (irrigating 4,040 hectares and above).
It will be seen from the table that the major and medium projects under operation and construction in the basin will irrigate an area of 1.86 million hectares on full development.

2.51 Ground water development in the Yamuna basin has been quite

Table 2.6

Projects Completed and Under Construction—Yamuna Basin

Name of Project	Location (District)	Date of completion	Estimated cost (Rs. million)	Ultimates irrigation (hectares)
1	2	3	4	5
Himachal Pradesh				
I. Completed Projects				
(a) Pre-Plan projects		NIL		
(b) Plan Projects		NIL		
II. Projects under construction		NIL		
Haryana				
I. Completed Projects:				
(a) Pre-Plan projects				
Eastern Yamuna Canal	Ambala		41.81	4,88,290
Western Yamuna Canal Extension			15.93	
(b) Plan Projects				
Dadri Irrigation	Mahendragarh	1955-56	7.67	Benefits shown under W.Y.C. Remodelling
II. Projects under construction				
Remodelling western Yamuna Canal	Rohtak Karnal Hissar	IV Plan	75.73	247,960
Gurgaon Canal	Gurgaon	IV Plan	83.60	101,580
Extension of irrigation from WYC to Rewari Lift	Rohtak Gurgaon Mahendragarh	IV Plan	16.00	27,830
Augmentation tubewells in WYC tract-Stage I	Ambala Karnal	IV Plan	10.58	10,170
		Total	251.32	8.75,830

Table 2.6—Contd.

1	2	3	4	5
Uttar Pradesh				
I. Completed Projects:				
(a) Pre-Plan Projects				
Eastern Yamuna Canal	Saharanpur	1854	7.20	191,430
Agra Canal	Delhi Mathura Agra	1873	13.28	138,360
Doon Canal	Dehradun	1863	2.68	10,920
Betwa Canal	Jhansi	1886	14.02	98,700
Dhasan Canal	Jhansi Hamirpur	1910	5.06	24,280
Ken Canal	Chhatarpur (MP)—Banda	1915	30.31	75,260
(b) Plan Projects				
Matatila Dam	Jhansi	1966	124.60	120,420
Saprar Dam	Jhansi	1955-56	9.55	17,000
Rangwan	Panna (MP)	1955-56	12.64	37,640
Arjun Dam	Hamirpur	1955-56	11.70	10,770
Lalitpur Dam	Jhansi	1952-53	4.32	7,580
Remodelling Eastern Yamuna Canal	Saharanpur Meerut Muzaffarnagar	1956-57	6.99	8,870
Remodelling Agra Canal	Delhi Mathura Agra	1962-63	8.02	8,260
Balmiki (Ohen) Sarovar	Banda	1964-65	10.00	6,270
Extension of 78 miles Ken canal	Banda	1966	1.03	4,280
Barwa Dam	Banda	1966	6.80	5,350
Projects irrigating less than 4,040 hectares (3 Nos.)			4.09	3,750
II. Projects under construction				
Jamni Dam	Jhansi	IV Plan	37.20	12,480
Chandrawal Dam	Hamirpur	IV Plan	10.60	4,310
		Total:	320.09	785,930
Rajasthan				
I. Completed Projects:				
(a) Pre-Plan Projects				
	NIL			
(b) Plan Projects				
Bharatpur Feeder	Bharatpur	1970	1.70	4,860

Table 2.6—Contd.

1	2	3	4	5
II. Projects under construction				
Gurgaon Canal	Bharatpur	IV Plan	30.20	25,090
		Total:	31.90	29.950
Madhya Pradesh				
I. Completed Projects:				
(a) Pre-Plan Projects				
Bhind Canals (Pagra dam and Pillowa Weir)	Bhind & Morena	1927	4.37	26,560
Parvati Project (Harsi and Kaketo Dams)	Gwalior	1934-37	9.22	30,770
Adda Dam	Morena	1934	2.37	4,300
Tigra Canal	Gwalior	N.A.	5.31	3,220
(b) Plan Projects				
Beniganj	Chhatarpur	1970-71	7.00	4,050
Projects irrigating less than 4,040 hectares (3 Nos.)			13.17	7,230
II. Projects under construction				
Bander Canal	Gwalior Datia	N.A.	N.A.	45,340
Bila	Sagar	1974	28.69	12,950
Removing shortage in Harsi system	Gwalior	IV Plan	45.24	23,880
Jassaiya	Guna	1973	11.79	5,400
Projects irrigating less than 4,040 hectares (3 Nos.)			18.68	7,910
		Total:	145.84	1,71,510
		Plus:	Bander Canal	
	Grand total for the basin:		749.15	1,863,220
				Plus: Bander Canal

Source: Central Water & Power Commission Note Volumes on Irrigation of respective States.

extensive. A large number of tubewells and wells have been sunk and a considerable area is irrigated by them. The following table shows the area irrigated in the basin under various sources like canals, tanks, wells, tubewells etc. during the year 1967-68.

Table 2.7

Source-wise Irrigation—Yamuna Basin

(Thousand hectares)

Source of irrigation	Himachal Pradesh	Haryana (Sangrur distt. of Punjab included)	Uttar Pradesh	Madhya Pradesh	Rajasthan	Delhi	Total
1	2	3	4	5	6	7	8
Canals	Neg.	683.0	869.2	110.9	36.6	8.1	1,707.8
Tanks	—	2.4	10.0	18.6	75.5	0.9	107.4
Wells & Tubewells	—	188.3	641.7	158.2	199.1	16.3	1,203.6
Other sources	6.0	9.1	14.6	5.2	0.8	—	35.7
Total	6.0	882.8	1,535.5	292.9	312.0	25.3	3,054.5

2.52 According to the data available, the deltas obtainable in some of the important projects in the basin are as follows:

Name of the Project	*Delta at Canal head*
Western Yamuna Canal System	0.76 m.
Eastern Yamuna Canal System	0.49 m.
Agra Canal	0.51 m.
Betwa Canal	0.63 m.
Ken Canal	0.86 m.

Taking the areas irrigated under each system into account, the average delta for the above schemes works out to 0.7 m.

2.53 The total area that will be brought under irrigation from all pre-Plan projects and all projects undertaken up to 1968-69 is of the order of 1.86 million hectares. Of these, it has been planned that the Gurgaon Canal (rabi requirements) and the Rewari lift will get water supply from the Beas Project. Also, the W.Y.C. tubewell project will utilise ground water. Making allowances for these projects, it can be said that an area of 1.8 million hectares will be served by the waters of the Yamuna basin. The total water diverted for irrigating 1.8 million hectares would be of the order of 12,335 m. cu. m.

Minor schemes such as, tanks utilising surface waters irrigate a very small part of the area in the basin. Hardly 5 per cent of the total area irrigated from all projects is under minor schemes (utilising surface water). The total area under minor schemes in 1968-69 was of the order of 1.52 million hectares. In the absence of any data regarding deltas obtained on the minor schemes, it has been assumed that the same delta as in major and medium schemes are obtainable in this case also. On this basis, water diverted by the minor schemes would be about 10,645 m. cu. m.

Reservoir Losses

2.54 On the basis of assumptions detailed in para 1.33 the reservoir losses from the various schemes in the basin will be as under:

(i) Major and medium schemes	925 m. cu. m.
(ii) Minor schemes (tanks)	1,131 m. cu. m.
Total	2,056 m. cu. m.

2.55 Thus, on completion and full development, the total water utilisation in the basin from all schemes undertaken up to 1968-69 would be of the order of 25,036 m. cu. m. (15,523 m. cu. m. of surface + 9,513 m. cu. m. of ground).

The Yamuna-Ganga doab is one of the most important regions in the entire Ganga basin and a number of industries are situated in it. With various facilities such as availability of electricity, water, good communications etc., the basin would, in future also attract a number of new industries. The water requirement of the industries—both now and in the future is considerable. The precise requirements are not available. However, this aspect has to be kept in view for the future development of the basin.

There have been reports of the pollution of the Yamuna due to the discharge of industrial and other wastes. With a number of industries and major cities and towns situated in the basin, this aspect has great significance and has to be kept in view in planning future development.

FUTURE DEVELOPMENT

2.56 According to the data for the period from 1959-60 to 1968-69, the average inflow of the Yamuna at Tajewala is 9,868 m. cu. m. The Western Yamuna Canal (including extension and the remodelling and kharif requirements of the Gurgaon Canal) will irrigate an area of approximately 0.8 million hectares. The average delta obtainable in the Western Yamuna Canal tract is 0.76 m. The water diverted, therefore, works out to nearly 6,167 m. cu. m. The Eastern Yamuna Canal irrigates an area of about 0.19 million hectares. The delta in the Eastern Yamuna tract is 0.5 m. The water diverted for this system works out to approximately 987 m. cu. m. Thus, the total water already being utilised at Tajewala is of the order of 7,154 m. cu. m. leaving about 2,714 m. cu. m. for future projects.

2.57 Two projects, namely the Lakhwar Dam across the Yamuna, about 20 km. upstream of Kalsi and the Kishau Dam accross the Tons, a major tributary of the Yamuna have been proposed by Uttar Pradesh for utilising the available surplus waters. These are, however, inter-State projects involving the concurrence of Haryana and Himachal Pradesh. Details of these two projects have not yet been finalised. However, it is expected that when these two schemes are implemented, all the water available up to Tajewala would be utilised. These two projects, in addition to increasing irrigation in the Western Yamuna Canal and the Eastern Yamuna Canal tracts and possibly in the Agra Canal area also will produce power and will control floods in the Yamuna.

After the Western and Eastern Yamuna Canals, the next major system taking off from the Yamuna is at Okhla near Delhi from where the Agra Canal takes off. The area irrigated by the Agra Canal is about 0.14 million hectares. It has been found that the fair weather flow of the Yamuna at Okhla is insufficient to meet the requirements of the Agra Canal and for this reason the water supply is being augmented from the Upper Ganga Canal through the Hindon cut.

Once the Kishau and the Lakhwar Dams have been constructed, there will be no surplus water available from the Yamuna up to Delhi for any further expansion of irrigation. No other major tributary joins the Yamuna downstream of Delhi up to the Chambal confluence. Any future expansion of irrigation has to be below the confluence of the Chambal with the Yamuna.

2.58 The average annual runoff of the Yamuna basin as a whole has been assessed at 65,621 m. cu. m. and the surface water utilisation from the projects so far undertaken (including the pre-Plan projects) would be of the order of 15,523 m. cu. m. leaving about 50,098 m. cu. m. of water for future development.

2.59 Apart from the Kishau and the Lakhwar Dams, the following projects are possible in the basin:

(A) *Projects investigated*
  (i) Sindh Project
  (ii) Bah Dam
  (iii) Sagar
  (iv) Ken Pumped Canal
  (v) Augusi Pumped Canal

(B) *Projects to be investigated*
  (i) Bhangarh Dam
  (ii) Jhaklum Dam
  (iii) Hastapur Dam
  (iv) Kurrat Dam
  (v) Sujara Dam
  (vi) Bhiram Dam
  (vii) Bewas Dam
  (viii) Gangau Dam
  (ix) Other small schemes

2.60 When all the above projects are implemented, the total additional area expected to be brought under irrigation (including 0.105 million hectares from the Kishau Dam and 0.156 million hectares from the Lakhwar Dam) would be of the order of 1.8 million hectares.

FLOODS, WATERLOGGING & DRAINAGE

2.61 The flood problem in the Yamuna basin is not as severe as those on some of the other tributaries of the Ganga. When the Yamuna is in flood it spills its banks and submerges low-lying areas in Haryana. The floods are normally of low magnitude and the problem can be stated to be only marginal. Embankments in different reaches have been constructed to protect the areas susceptible to floods.

In the Delhi territory, the Yamuna in the past used to flood low-lying areas on both banks. Marginal embankments have gradually been constructed and most of the areas have now been protected.

In Uttar Pradesh, the Yamuna river is generally well-set. The flood spills, however, occur in the districts of Muzaffarnagar, Saharanpur and Meerut in the upper reaches and Banda and Allahabad districts in the lower reaches. Flooding in Uttar Pradesh by the Yamuna water is not frequent. However, poor drainage of the adjoining territories, encroachment by habitation and the choking of the natural drainage lines, do cause some flooding in the districts mentioned above. Remedial measures are being taken from time to time.

2.62 In the Western Yamuna Canal command area in Haryana considerable area suffers from waterlogging (the water-table being within 1.5 m. from ground level). During October 1966, nearly 0.234 million hectares were waterlogged. The State Government are taking steps to remedy the situation by constructing surface drains, drawing out ground water by tubewells etc. Surface drains of total length of nearly 1,630 km have been constructed in the waterlogged areas. 256 No. tubewells have been installed along the main line and main branch of the W.Y.C. These tubewells in addition to supplementing the water in the canal, will also keep the water-table levels in check. Recently 128 more tubewells have been installed along these channels. The State Government has also investigated schemes for installing 100 tubewells along the Delhi Branch Canal. To relieve waterlogging along the Hansi Branch the Hansi Anti-waterlogging scheme has been implemented. It involves the construction of seepage drains on both sides of the Hansi Branch with pumps at suitable locations to lift seepage water into the canal. Besides, pumps have been installed to de-water the natural depressions which get filled with water during the monsoons.

2.63 In Uttar Pradesh also, waterlogging prevails in the irrigated areas under the Eastern Yamuna Canal and Agra Canal. The areas close to big canals in heavy filling reaches are affected. In order to reduce the extent of waterlogging open seepage drains have been constructed near the canals.

There are no reports of waterlogging and drainage problems in other basin States viz. Madhya Pradesh and Rajasthan.

SOIL CONSERVATION

2.64 The problem of soil erosion in the basin is particularly serious in the Himalayan tract covering parts of the Sirmur, Mahasu, Simla, Tehri-Garhwal and Dehradun districts. The soils in this region are very thin and all exposed slopes are susceptible to severe sheet erosion and gullying. Landslides are fairly common in the area. Lower down, in the plains the slopes are gentle, except in the vicinity of natural drainages where steep slopes have been created through erosion spread over centuries. Destructive erosion first starts from the banks of natural drainages where the runoff has to negotiate steep slopes. The banks have been denuded of their vegetal cover and in almost all cases cultivation has been carried to the water line. The most common type of erosion is gullying and ravine formation. Gully erosion is a severe problem in the Shivpuri and Gwalior districts.

Soil erosion is more critical in the areas where over-grazing by livestock is permitted on the hill-pastures and in the pastured woodlands. Some accelerated erosion is caused where cultivation has been extended up to the hill slopes.

The basin has 11.5 per cent of the area under forests. The percentage is low when compared with the all-India average and the standards laid down in the Forest Policy Resolution of the Government passed in 1952. Afforestation of the catchment is called for to reduce erosion hazards.

Under the centrally sponsored programme of soil conservation in the catchments of major river valley projects, no project in the basin has been included.

2.65 A capacity survey of the Matatila reservoir, across the Betwa river, was done in the pre-monsoon period of 1966. The reservoir has a gross storage capacity of 1,132 m. cu. m. of which 780 m. cu. m. is the live storage and the balance of 352 m. cu. m. dead storage. The capacity survey indicated that the annual rate of siltation was of the order of 0.034 m. cu. m. per 100 sq. km. of the net catchment area against the annual rate of 0.014 m. cu. m. per 100 sq. km. assumed in the project estimates.

Observations of silt load are also being carried out since 1962. The details of silt trapped annually for the period 1962 to 1967 are given below: *

Table 2.8

Siltation of Matatila Reservoir

Year	Silt (suspended load + bed load) trapped in the reservoir in m.cu.m.
1	2
1962	3.87
1963	4.87
1964	5.02
1965	8.00
1966	4.01
1967	11.70
Total	37.47

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*Sedimentation data of selected reservoirs in India (revised edition), Central Water and Power Commission, March 1969 (unpublished).

An analysis of the above data shows that the total silt load trapped in the reservoir, including the bed load, from 1962 to 1967, is of the order of 37.47 m. cu. m. i.e. 6.24 m. cu. m. on an average annually. This works out to 0.03 m. cu. m. per 100 sq. km. of the net catchment area.

The results of both the capacity survey and the silt inflow-outflow studies show that the rate at which the siltage is taking place in the reservoir is more than twice the rate of siltation assumed in the project estimates. Soil conservation measures in this catchment area need to be taken up urgently.

SALIENT FEATURES OF THE RAMGANGA BASIN

(i) Source: Near village Lohba in the Garhwal district of Uttar Pradesh (Latitude 30°5′-N, Longitude 79°16′-E).

(ii)	Length	596 km.	370 miles
(iii)	Drainage area	32,493 sq. km.	12,545 sq. miles
(iv)	Population (1971 Census)	8.23 millions	
(v)	Density of Population	253 per sq. km.	655 per sq. mile
(vi)	Average annual runoff	18,626 m.cu.m.	15.1 MAF

		Thousand hectares	Thousand acres
(vii)	Culturable area (1967-68)	2,078	5,135
(viii)	Net area sown (1967-68)	1,842	4,552
(ix)	Gross area sown (1967-68)	2,393	5,913
(x)	Net area irrigated (1967-68)	382	943
(xi)	Gross area irrigated (1967-68)	442	1,092
(xii)	Ultimate irrigation by major and medium projects under operation and construction, in 1968-69	953	2,355

			m.cu.m.	MAF
(xiii)	Water utilisation, including reservoir losses on completion and full development of major, medium and minor projects under operation and construction 1968-69	Surface water	7,144	5.79
		Ground water	1,446	1.17
		Total	8,590	6.96

CHAPTER III

THE RAMGANGA BASIN

The Basin

The Ramganga basin extends over an area of 32,493 sq. km., and lies between east longitudes 78°15′ to 80°5′ and north latitudes 27°5′ to 30°6′, in Uttar Pradesh. The basin is bounded on the north by the Siwalik range of the Himalayas, on the east by the ridge separating it from the Gomti basin and on the south and west by the ridge separating it from the basin of the main Ganga river. The basin is petal shaped with a maximum length of 325 km. in the northwest-southeast direction and a maximum width of 160 km. in the northeast-southwest direction.

THE RIVER SYSTEM

3.2 The Ramganga river is the first major tributary of the Ganga to join it on its left bank. It rises in the lower Himalayas at an altitude of about 3,110 m. above mean sea level, at north latitude 30°5′ and east longitude 70°16′, near the village of Lohba in the Garhwal district of Uttar Pradesh. In the head reach, the river flows in a south-easterly direction for about 32 km. through Garhwal district. Thereafter, it flows in a south-westerly direction successively through Almora and Garhwal districts for about 112 km. During its course in these districts, the river flows through mountainous terrain and has a number of falls and rapids. The river emerges from the hills into the plains at Kalagarh near the border of Garhwal district. The Ramganga project, which will supply water to the Upper and Lower Ganga Canals in addition to areas under its own command, is under construction at Kalagarh. Beyond Kalagarh, the river flows in a south-easterly direction through the districts of Bijnor, Moradabad, Budaun, Rampur, Bareilly and Shahjehanpur and finally joins the Ganga, near about Kannauj in the Fategarh district. The total length of the river from the source to its outfall into the Ganga is 596 km. and the entire length lies in Uttar Pradesh.

3.3 A number of tributaries join the river mostly from the left. The important tributaries are the Khoh, the Gangan, the Aril, the Kosi and the Deoha (Gorra).

CLIMATE

3.4 In the hilly region of the basin, the climate is temperate with cool summers and cold winters. The plains have a tropical climate with hot summers (the temperature in May and June ranging up to 43°C) and cold winters (the temperature coming down to 7°C in the months of December and January).

3.5 The basin receives most of its rainfall during the southwest monsoon season from June to September. The northern districts near the hills receive comparatively more rain than the districts in the plains. The rainfall in the hill districts of Almora, Nainital and Garhwal, during the summer months (March to May) is also not insignificant. The average annual and monsoon rainfalls in the different districts lying in the basin are given below:

Table 3.1

Rainfall in the Ramganga Basin

District	Average annual rainfall (mm)	Monsoon rainfall (mm)
1	2	3
Almora	1,045	773
Naini Tal	1,566	1,386
Garhwal (Pauri)	1,303	967
Bijnor	1,088	928
Pilibhit	1,242	1,085
Moradabad	944	815
Rampur	N.A.	N.A.
Bareilly	1,107	960
Farukhabad	793	703
Shahjehanpur	1,020	891
Budaun	821	711
Hardoi	879	772
Lakhimpur (Kheri)	1,069	922

Source IMD—Monthly and Annual Normals of rainfall and of rainy days (1901-50).

Evaporation

3.6 There are no departmental or agro-meteorological observatories of the India Meteorological Department located in the basin.

Soils

3.7 No detailed soil survey of the basin has yet been made. However, the general data regarding the soils of India indicate that mainly alluvial, terai and brown hills soils occur in the basin. The principal soil types found in the various districts lying in the basin are given below.*

Table 3.2

Soils in the Ramganga Basin

District	Type of soil
1	2
Almora	Brown hill
Naini Tal	Alluvial, terai and brown hill
Garhwal (Pauri)	Terai and brown hill
Bijnor	Alluvial and terai
Pilibhit	Alluvial and terai
Moradabad	Alluvial
Rampur	Alluvial and terai
Bareilly	Alluvial and terai
Farrukhabad	Alluvial
Shahjehanpur	Alluvial
Budaun	Alluvial
Hardoi	Alluvial
Lakhimpur (Kheri)	Terai

LAND USE & AGRICULTURAL PRACTICES

3.8 Land use details in the Ramganga basin in 1967–68 are given in Table 3.3.

Agriculture is practised in the basin very extensively. Out of a total reporting area of 3.22 million hectares, 2.08 million hectares (64.5%) are culturable, and an area of 1.84 million hectares (88.6%) of culturable area is cultivated annually. The area irrigated constitutes 20.7% of the cultivated area in the basin.

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*Indian Crop Calendar, Ministry of Food, Agriculture, Community Development and Cooperation (1967).

Table 3.3

Land Use Details in the Ramganga Basin

Classification	Area in thousand hectares
1	2
Geographical area	3,249
Reporting area	3,221
Area under forests	700
Area not available for cultivation	443
Culturable area	2,078
Uncultivated culturable area	236
Net area sown	1,842
Area sown more than once	551
Total cropped area	2,393
Net irrigated area	381.5
Gross irrigated area	442
Percentage of net area sown to culturable area	88.6
Percentage of net irrigated area to net area sown	20.7

3.9 The general agricultural practice in the Ramganga basin is the same as in other northern parts of India. In the hill districts of Garhwal and Almora, practically the whole of the cultivated area is covered by food crops. Of the food crops rice, wheat and barley predominate with inferior cereals like maize, jowar, bajra covering only a small percentage of the total area. In the remaining districts also, food crops constitute 85–90 per cent of the total cultivated area. Rice, wheat, barley, sugarcane and pulses form the bulk of crops while the inferior cereals like bajra, jowar and maize are grown over small areas. Among the non-food crops, oil seeds (groundnut, linseed, rape, mustard) are the most important, while in some districts tobacco is grown over considerable areas.

3.10 The crop pattern under irrigated conditions remains more or less the same as under rain-fed conditions. In this case also, food crops like sugarcane, wheat and barley and rice (in that order) predominate. Among non-food crops, tobacco and fodder crops are important. Details of irrigated crops in the basin during 1967–68 are given in Table 3.4.

Table 3.4

Irrigated Crops in the Ramganga Basin

Name of crop	Area thousand hectares	Percentage to total
1	2	3
Rice	107.4	24.3
Wheat & Barley	175.8	39.8
Sugarcane	81.2	18.4
Other food crops	58.8	13.3
Total food crops	423.2	95.8
Total non-food crops	18.80	4.2
Total cropped area	442.00	100.0

Crop Seasons

3.11 The main crop seasons are the kharif and rabi. Under rain-fed conditions, rice and lower order cereals like maize, bajra and jowar are grown during kharif. The rabi crops are wheat, barley, pulses etc. Under irrigated conditions, rice is also grown as rabi crop.

REGIONAL ECONOMY

Population

3.12 On the basis of the 1971 Census* and the percentage of the area of each district within the basin to the district as a whole, the total population in the basin is about 8.23 millions, giving a density of population of 253 persons per sq. km. The three hill districts of Almora, Nainital and Garhwal are sparsely populated. Bareilly district has the highest density with 431 persons per sq. km. while the Garhwal district (including Chamoli) has the lowest figure of 58 persons per sq. km.

Bareilly, Moradabad, Rampur and Shahjehanpur are the four cities in the basin with a population of more than one lakh each. Of the total population in the basin, nearly 86.2 per cent live in rural areas while the rest live in urban areas. In the more populated districts of Bareilly Moradabad and Rampur, the percentage of people living in urban areas is, merely 22 per cent of the total population. The working force constitutes 32.2 per cent of which 56.0 per cent are engaged as cultivators, 19.3 per cent as agricultural labourers and the rest in other services.

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*Census Paper I of 1971 (Supplementary), Registrar-General (India).

Forests and Agriculture

3.13 Forests occupy nearly 21.7 per cent of the total geographical area of the basin, mainly in the hilly districts of Almora, Nainital and Garhwal and to some extent in the Pillibhit districts. The rest of the basin forms part of the Gangetic Plains, where agriculture is practised very extensively. Nearly 89 per cent of the cultural area is cultivated annually.

Compared to other areas in Uttar Pradesh, irrigation development in the Ramganga basin has not been on a large-scale. 20.7 per cent of the cultivated area in the basin is provided with irrigation against the overall figure of about 28 per cent for the State.

Power

3.14 The total hydro-power potential of the Ramganga basin has been assessed by the CW&PC as 54 MW at 60% load factor. The Ramganga Project with an installed capacity of 198 MW, which is under construction at present, will fully develop the hydro-power potential of the basin.

Mineral Wealth

3.15 Uttar Pradesh ranks very low among the States as regards mineral resources. The major portion of the State is covered by alluvium where no minerals are found. Known mineral occurrences are confined to the Himalayan region in the north and the Bundelkhand region in the south-west.*

Limestone deposits: In the Garhwal, Chamoli and Nainital districts. The Garhwal deposits are estimated to be of the order of 206 million tonnes.

Phosphatic shale: Extensively in the Garhwal district. But its phosphoric acid content is too low for the manufacture of phosphatic fertilisers.

Magnesite: In the Dewaldhar area near Almora.

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*Techno-Economic Survey of Uttar Pradesh, NCAER.

Industries

3.16 There are hardly any major industries situated in the basin. Sugarcane is one of the important crops grown in the area and as a result, the sugar industry has well developed. There are some silk mills in Shahjehanpur. Among the light engineering industries, mention can be made of the bicycle industry in Bareilly, and the manufacture of copper and brass vessels in Moradabad.

Communications

3.17 Most of the important towns and cities in the basin are connected by rail and road. Both the broad-gauge railway line and the National Highway from Delhi to Lucknow pass through the major cities (Rampur, Moradabad, Bareilly, Shahjehanpur) lying in the basin. In addition, the basin is also served by networks of the metre-gauge railway, and State, district and village roads.

The Ramganga and its tributaries are not navigable.

WATER RESOURCES

Surface Water

3.18 The surface water potential of the Ramganga river system had been first assessed in 1949 on the basis of Khosla's empirical formula. The combined annual runoff of the Ganga and the Ramganga up to their confluence was estimated to be 40,261 m. cu. m.* In 1960 when the irrigation potential studies of the country were made by the Central Water & Power Commission, the total annual runoff of the Ramganga river system was assessed to be 18,626 m. cu. m. based on the available runoff data of an identical catchment.**

There is one gauge-discharge site maintained by the Uttar Pradesh State Government on the main river at Raini weir from where the Ramganga Canal takes off.

Ground Water

3.19 The Geological Survey of India has investigated the possibilities of the development of ground water resources in the Tarai-Bhabar region of the Nainital and Bijnor districts.* In the Tarai belt, the near surface ground water is unconfined but the deeper aquifers occur under confined conditions in the Bhabar region. The southern portion of the Bhabar belt and the entire Tarai belt have very good ground water potentialities. Large-scale ground water development by deep tubewells is feasible in the Bhabar-Tarai belt. No quantitative assessment of the ground water has so far been made.

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*An appraisal of water resources by Dr. A. N. Khosla, UNESCO.

**Report of the technological possibilities of irrigation projects in India, Central Water & Power Commission (unpublished).

In the Farukhabad district, part of the area lying in the basin has been investigated for ground water. Ground water occurs both under water table and confined conditions. Tubewells of depths from 60 to 150 m. yield between 68,000 and 159,000 litres per hour.

EXISTING DEVELOPMENT

3.20 Prior to the commencement of the First Five Year Plan, there were four important Canal Systems in the Ramganga basin. They were the Ramganga Canal (irrigating 19,520 hectares in Bijnor and Moradabad districts), the Bijnor Canals (irrigating 16,600 hectares in Bijnor district), the Rampur Canal (irrigating 17,640 hectares in Rampur and Moradabad districts) and the Rohilkhand Canal (irrigating 64,570 hectares in Nainital district). In addition some areas in the basin were irrigated under the Sarda Canal, which drew a part of its supplies for irrigating these areas from the Deoha, the Bahgul and the Kailash rivers which are tributaries of the Ramganga.

3.21 After the commencement of the planned development of projects, the most important project to be undertaken in the basin is the Ramganga Project of which work was started during the Second Plan period and is expected to be completed in the Fifth Plan. The project envisages a main dam, 126 m. high and 626 m. long, in earth and rockfill across the river Ramganga, three km. from Kalagarh in the Garhwal (Pauri) district and a saddle dam 72 m. high and 579 m. long, across the Chuisot, a tributary of the Ramganga. The reservoir will have a live capacity of 1,937 m. cu. m. (gross capacity 2,196 m. cu. m.). There will be a feeder channel to divert the water of the Ramganga into the Ganga and the project envisages the improvement of the intensity of irrigation under the Upper and Lower Ganga Canals, Agra Canal (Yamuna Basin) and the Ramganga Canal. An area of 666,000 hectares is expected to be provided with irrigation facilities on completion of the project. In addition, the project envisages the generation of electricity, at the power station whose installed capacity is 198 MW. The project is estimated to cost Rs. 968.6 million.

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*Ground Water Resources of India, Status and Surveys, Prospect and Perspectives, Geological Survey of India (August, 1970).

3.22 A number of medium schemes have also been undertaken in the basin. The details of all major and medium projects completed and under construction in 1968–69 are given below:*

Table 3.5

Projects Completed and Under Construction in the Ramganga Basin

Name of Project	Location (District)	Date of completion	Estimated cost (Rs. million)	Ultimate irrigation (hectares)
1	2	3	4	5
(i) COMPLETED PROJECTS				
Pre-Plan Projects				
Rohilkhand Canal	Nainital	1894	2.81	64,570
Ramganga Canal	Bijnor-Moradabad	1931	3.06	19,520
Bijnor Canal	Bijnor	N.A.	0.60	16,600
Rampur Canal	Rampur-Moradabad	N.A.	0.18	17,640
Plan Projects				
Afzalgarh Canal	Bijnor	1961-62	1.87	4,050
Nanaksagar	Nainital	1963-64	42.04	53,710
Tumaria Reservoir	-do-	1966	21.63	16,190
Pili Reservoir	Bijnor	1967-68	24.00	11,500
Tumaria Extension	Nanital	1967-68	27.00	18,200
Baur Reservoir	-do-	1967-68	34.00	18,900
East Baigul Reservoir	-do-	1968-69	10.60	7,240
(ii) PROJECTS UNDER CONSTRUCTION				
Ramganga Project	Garhwal	V Plan	968.60	6,66,000
Haripura Reservoir	Nanital	IV Plan	26.83	20,000
Kosi Irrigation Scheme	-do-	IV Plan	28.80	19,020
Total			1,192.02	9,53,140

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*Note Volume on irrigation Chapter, Uttar Pradesh, Central Water and Power Commission (1970).

3.23 When all the projects so far undertaken are completed and fully developed, the total area under irrigation will be nearly one million hectares. There are also a number of minor schemes, mainly tubewells, in the basin irrigating a considerable area. The areas irrigated in the basin under various sources like canals, tanks, wells, tubewells etc. during 1967–68 are given below:

Table 3.6

Source-wise Irrigation—Ramganga Basin

Source of irrigation 1	Area irrigated (Thousand hectares) 2
Canals	177.5
Tanks	8.3
Wells (including tubewells)	182.3
Other sources	13.4
Total	381.5

The main sources of irrigation in the basin are the canals and the tubewells. Tanks have a very small area under them.

3.24 The deltas realised in the existing projects are given below:

Ramganga Canals	0.6 m.
Rohilkhand Canal	1.3 m.
Rampur Canal	1.4 m.
Bijnor Canal	0.5 m.

The deltas in the upper and Lower Ganga Canals where the waters of Ramganga Project (under construction) are to be utilised are 0.57 m. and 0.71 m. Giving proper weightage to the areas to be irrigated under the respective commands, an average delta of 0.61 m. can be assumed for the basin as a whole. On this assumption, the total water requirement for the 0.95 million hectares which will be brought under irrigation from all the major and medium projects undertaken up to 1968–69 will work out to 5,871 m. cu. m. Minor schemes irrigated an area of 0.27 million hectares in 1968–69, using approximately 1,618 m. cu. m. of water.

Reservoir Losses

3.25 On the basis of assumptions detailed in para 1.33 the reservoir losses from the various schemes in the basin will be as under:

(i) Major and medium schemes	1,000 m. cu. m.
(ii) Minor schemes (tanks)	101 „
Total	1,101 m. cu. m.

Thus, the total water utilisation under all the major, medium and minor schemes under operation and under construction in the basin in 1968–69 would be 8,590 m. cu. m. (7,144 m. cu. m. of surface water + 1,446 m. cu. m. of ground water).

The Ramganga Project, with an installed capacity of 198 MW, on its completion, is bound to give a great fillip to industrial development in the basin. Future development of water resources should take into account the industrial water requirements also.

FUTURE DEVELOPMENT

3.26 As has been stated in para 3.18, the average runoff in the basin is of the order of 18,626 m. cu. m. whereas the total surface water utilisation from all existing schemes and schemes undertaken up to 1968–69 will be of the order of 7,144 m. cu. m. A balance of nearly 11,482 m. cu. m. is still available in the basin for future projects.

The U.P. Govt. has not proposed any new major schemes in the basin except those which are already under construction (Ramganga, Haripura and Kosi Irrigation projects) during the Fourth Plan period. There are also no new schemes being investigated.

FLOODS, WATERLOGGING AND DRAINAGE

3.27 The Ramganga has a shifting and uncertain course during its course in the plains. During floods, the river overlaps its banks opening out new channels and destroying the fertility of the land by depositing coarse sand in it. In the districts of Hardoi, Farrukhabad, Shahjehanpur, Budaun, Bareilly, Rampur, Moradabad and Bijnor, floods cause serious damage. However, the extent of the area flooded is not large except near its confluence with the Ganga. The villages along the river are generally on the high bank of the river. The flood problem in the basin is not very serious. Waterlogging and drainage problems have not been reported.

SOIL CONSERVATION

3.28 The problem of soil erosion in the basin is particularly serious in the hilly districts of Almora, Nainital, Garhwal and to some extent in Pilibhit. Soil erosion occurs due to faulty agricultural practices like ploughing through the contours of unbunded fields. Large-scale unplanned felling and thinning of trees and uncontrolled grazing in the forests also cause soil erosion.

The Ramganga project has been included under the centrally sponsored programme of soil conservation in catchments of major river valley projects. Up to the end of the Annual Plans (1966–69), an area of 13,000 hectares was covered by soil conservation works at a cost of Rs. 10.175 million.

3.29 Observations of the suspended silt load at Kalagarh on the Ramganga river are being taken by the Ramganga project authorities since 1958. The gross storage capacity of the reservoir is 2,450 m. cu. m. of which 2,196 m. cu. m. is the live storage and the balance 254 m. cu. m. the dead storage. The details of silt load carried by the river during the period 1958 to 1967 are given below:*

Table 3.7

Silt Load at Kalagarh Carried by the Ramganga River

Year	Silt (suspended load) carried by the river in m.cu.m
1	2
1958	5.94
1959	3.44
1960	3.62
1961	5.93
1962	9.41
1963	3.33

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*Sedimentation data of selected reservoirs in India (revised edition), Central Water & Power Commission, March 1969 (unpublished).

Table 3.7—Contd.

1	2
1964	1.36
1965	0.42
1966	12.82
1967	4.09
Total	50.41

3.30 An analysis of the above data shows that the total suspended silt carried annually by the river from 1958 to 1967 is of the order of 50.41 m. cu. m. i.e. 5.04 m. cu. m. on an average. Adding 15% of suspended load as deposition in the reservoir per annum, this works out to 5.04+0.76=5.80 m. cu. m. against the annual rate of siltation of 1.34 m. cu. m. assumed in the project estimates.

The rate at which silt is probably being deposited in the reservoir storage is over four times the rate of siltation assumed in the project estimates. Though it would be misleading, at present, to predict the life of the reservoir mathematically, the very fact that siltation rate is much higher than that assumed underlines the necessity and urgency of implementing soil conservation measures in the catchment.

SALIENT FEATURES OF THE BASIN OF TONS, KARAMNASA AND OTHER RIVERS BETWEEN THE YAMUNA AND THE SON

(i)	Source:	The Tons	At Tamaskund in the Satna district of Madhya Pradesh (Latitude 24°2′N, Longitude 80°29′E).
		The Karamnasa	Near Sarodag in the Mirzapur distt. of Uttar Pradesh (Latitude 24°37′N, Longitude 83°37′E).
		The Karunauti	Near Meja in the Allahabad district of U.P. (Latitude 25°7′N, Longitude 82°3′E).
		The Khajuri	Near Marihar in the Mirzapur distt. of U.P. (Latitude 24°56′N, Longitude 82°39′E).
		The Jirgo	South of Sakteshgarh in the Mirzapur district of Uttar Pradesh (Latitude 24°54′N, Longitude 82°53′E).

(ii)	Length:	The Tons	264 km.	164 miles
		The Karamnasa	192 km.	119 miles
		The Karunauti	47 km.	29 miles
		The Khajuri	45 km.	28 miles
		The Jirgo	58 km.	36 miles
(iii)	Drainage area	The Tons	16,860 sq. km.	6,510 sq. miles
		The Karamnasa & other rivers	11,709 sq. km.	4,520 sq. miles
		Total	28,569 sq. km.	11,030 sq. miles

(v)	Population (1971 Census):	6.83 millions	
(vi)	Density of Population	239 per sq. km.	619 per sq. mile
(vii)	Average annual runoff	14,123 m.cu.m.	11.45 MAF

		Thousand hectares	Thousand acres
(viii)	Culturable area (1967-68)	1,897	4,688
(ix)	Net area sown (1967-68)	1,480	3,657
(x)	Gross area sown (1967-68)	1,938	4,789
(xi)	Net area irrigated (1967-68)	394	974
(xii)	Gross area irrigated (1967-68)	488	1,206
(xiii)	Ultimate irrigation from the major & medium projects under operation and construction in 1968-69	404	998

			m.cu.m.	MAF
(xiv)	Water utilisation, including reservoir, losses on completion & full development from minor projects under operation in 1968-69	Surface water	3,819	3.01
		Ground water	1,126	0.91
		Total	4,945	4.01

CHAPTER IV

BASIN OF TONS, KARAMNASA AND OTHER RIVERS BETWEEN THE YAMUNA AND THE SON

The basin extends over an area of 28,569 sq. km., and lies between east longitudes 80°10′ to 80°50′ and north latitudes 23°48′ to 25°43′. Lying to the north of the Vindhya range, the basin covers large areas in the States of Madhya Pradesh, Uttar Pradesh and Bihar. The State-wise distribution of the drainage basin is given below:

Madhya Pradesh	12,328	sq km.
Uttar Pradesh	10,909	„
Bihar	5,332	„
Total	28,569	„

4.2 The basin is bounded on the north by the Ganga, on the east by the ridge separating it from the Son basin, on the south by the Vindhya range and on the west by the ridge separating it from the Yamuna basin. The basin is of irregular shape and has a maximum length of 365 km. in the east-west direction and a maximum width of 120 km. in the north-south direction.

THE RIVER SYSTEMS

4.3 *The Tons river* rises at Tamaskund, a tank in the Kaimur range of hills in the Satna district of Madhya Pradesh, at an elevation of 610 m. above the mean sea level at north latitude 24°2′ and east longitude 80°29′. The river flows first in a north easterly direction for about 192 km. and after traversing the rough hilly country round Maihar, flows through the fertile land of the Rewa and Satna districts. Near Satna town the river receives the Satna from the left and lower down reaches the edge of the plateau of Purwa where with its other affluents, the Bihar and the Chachai, it forms a series of water falls. The biggest water fall is that of its tributary the Bihar which falls through a height of 113 m. The Tons itself descends by about 61 m. and flows through a plain. It enters Uttar Pradesh at Deoria in the Allahabad district and after receiving the Belan, a major tributary on its right, flows to join the Ganga about 31 km. downstream of the confluence of the Ganga and Yamuna. The river has a total length of about 264 km. of which 202 km. are in Madhya Pradesh and the balance of 62 km. in Uttar Pradesh. The important tributaries of the Tons are the Belan (Drainage area 4,955 sq km.) the Satna (1,582 sq. km.) and the Bihar nadi (1,663 sq. km.).

4.4 *The Karamnasa* rises near Sarodag on the northern face of the Kaimur range about 29 km. west of Rohtasgarh in the Mirzapur district of Uttar Pradesh at an elevation of 350 m. at north latitude 24°37′ and east longitude 83°37′. It flows in a north westerly direction through the plains of Mirzapur till Lalitpur village. Entering the Varanasi district near Govindpur, the river flows on to join the Ganga near Chanusa. Its important tributaries are the Durgavati and the Chandraprabha. The Durgavati drains areas in the Shahabad district in Bihar. The river has a total length of 192 km. of which 116 km. lie in Uttar Pradesh and the balance 76 km. form the common boundary between Uttar Pradesh and Bihar.

4.5 *The Karunauti nadi* has its origin in Allahabad district at an elevation of 100 m. at north latitude 25°7′ and east longitude 82°8′. It flows first in a north-easterly direction and then in an easterly direction in the districts of Allahabad and Mirzapur and finally joins the Ganga near Birohi. The river has a total length of 47 km.

4.6 *The Khajuri* is formed by the confluence of the two nallahs, the Chandri and the Siktai which rise near Marihar in the Mirzapur district at an elevation of 180 m. at north latitude 24°56′ and east longitude 82°39′. The river joins the Ganga near Bidauli in Mirzapur district. The river has a total length of 45 km.

4.7 *The Jirgo* rises about 10 km. south of Sakteshgarh in Mirzapur district at an elevation of 185 m. at north latitude 24°54′ and east longitude 82°53′. For the first 13 km. the river flows in a northerly direction and then for about 26 km. it flows in a north-easterly direction, where it is joined by Barhinadi. It joins the Ganga about 5 km. west of Gangpur. Its total length is 58 km.

CLIMATE

4.8 The basin experiences a maximum temperature of 45–48°C during the summer months and a minimum of 4°C during winter. The hottest months are May and June and the coldest month is January.

4.9 The rainfall is chiefly confined to the south-west monsoon season from June to September. Nearly 90 per cent of the total annual rainfall is received during these months. The basin also receives occasional winter rains, though small in quantity. The winter rains are beneficial to rabi crops like wheat and barley. The average annual and monsoon rainfalls in various districts lying in the basin are given below:

Table 4.1

Rainfall in the Basin

(*mm*)

Name of District	Average annual rainfall	Monsoon rainfall
1	2	3
Madhya Pradesh		
Satna	1,100	967
Rewal	1,236	1,091
Panna	1,176	1,060
Sidhi	1,248	1,102
Uttar Pradesh		
Allahabad	976	865
Mirzapur	1,134	998
Benaras (Varanasi)	1,056	926
Ghazipur	1,052	926
Banda	946	851
Bihar		
Shahabad	1,123	984

Source: IMD—Monthly and Annual normals of rainfall and of rainy days (1901-50).

4.10 There are no departmental or agro-meteorological observatories of the India Meteorological Department within the basin.

SOILS

4.11 Detailed soil survey of the basin has not been made. However, the general data regarding the soils of India indicates that mainly alluvial, red and yellow, mixed red and black and red sandy soils occur in the basin.*

Principal soil types found in the various districts lying in the basin are given below:

Table 4.2

Soils in the Basin

District	Type of soil
1	2
Madhya Pradesh	
Satna	Mixed red and black.
Rewa	Medium black, red and yellow and mixed red and black.
Panna	Mixed red and black.
Sidhi	Red and yellow and medium black.
Uttar Pradesh	
Allahabad	Red and yellow and alluvial.
Mirzapur	Red and yellow and alluvial.
Varanasi	Red and yellow and alluvial.
Ghazipur	Alluvial.
Banda	Mixed red and black and alluvial.
Bihar	
Shahabad	Red and yellow and alluvial.

LAND USE AND AGRICULTURAL PRACTICES

4.12 Land use details in the basin for the year 1967–68 are given in Table 4.3.

Agriculture is practised quite extensively in the basin. Nearly 70 per cent of the reporting area is culturable and the area cultivated constitutes 80 per cent of the culturable area.

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*Indian Crop Calendar, Ministry of Food, Agriculture, Community Development and Cooperation (1967).

Table 4.3

Land Use Details in the Basin

(Thousand hectares)

Classification	State			
	Madhya Pradesh	Uttar Pradesh	Bihar	Total
1	2	3	4	5
Geographical area	1,233	1091	533	2,857
Reporting area	1,211	1091	531	2,833
Area under forests	193	241	83	516
Area not available for cultivation	207	143	69	420
Culturable area	811	707	379	1,897
Uncultivated culturable area	230	159	28	417
Net area sown	581	548	351	1,480
Area sown more than once	100	180	178	458
Total cropped area	681	728	529	1,938
Net irrigated area	4	175	215	394
Gross irrigated area	4	186	298	488
Percentage of net irrigated area to net area sown	0.7	31.9	61.3	26.6
Percentage of net area sown to culturable area	71.7	77.5	92.4	80.0

4.13 With the construction of a number of schemes in the basin, irrigation has been provided to nearly 27 per cent of the net area cultivated annually. Two main sources of irrigation are the canals and tubewells (and wells in the hilly areas of Madhya Pradesh and Uttar Pradesh). The area under tanks is hardly 10 per cent of the total area irrigated. During 1967–68, the area irrigated by canals constituted nearly 53.8 per cent, and under wells and tubewells 32.8 per cent. Area under tanks was about 6.0 per cent and the rest was under other sources.

4.14 A characteristic of the agricultural pattern of the basin is that nearly the whole of it is under food crops. The important crops are paddy, wheat, barley and pulses. Inferior cereals like bajra, maize and jowar are also grown over a small area.

4.15 The crop pattern under irrigated conditions is the same except that the area under paddy has gone up at the expense of that under cereals like, jowar, maize and bajra. While in Uttar Pradesh, areas under paddy and wheat and barley are more or less equal, in Bihar, paddy predominates. The details of irrigated crops during 1967–68 are given below:

Table 4.4

Irrigated Crops in the Basin

(Thousand hectares)

Name of crop	State					
	Madhya Pradesh		Uttar Pradesh		Bihar	
	Area	% to total	Area	% to total	Area	% to total
1	2	3	4	5	6	7
Rice	0.9	21.7	65.3	35.2	193.6	64.5
Wheat & gram	1.3	32.2	40.5	21.8	89.6	30.0
Surgarcane	0.1	1.8	12.1	6.5	4.1	1.4
Other food crops	1.4	38.7	67.4	36.4	11.7	3.9
Total food crops	3.7	94.4	185.3	99.9	298.0	99.8
Non-food crops	0.3	5.6	0.3	0.1	0.5	0.2
Total cropped area	3.9	100.0	185.6	100.0	298.5	100.0

4.16 The main crop seasons are kharif and rabi. The Kharif season begins with the onset of the south-west monsoon in June and extends up to October, whereas the rabi season starts after the monsoon and extends up to March or April. Rice, and cereals like maize, jowar etc. are kharif crops while wheat and barley are rabi crops. Under irrigated condition rice is also grown as a rabi crop.

REGIONAL ECONOMY

Population

4.17 On the basis of the 1971 census* and the percentages of the area of each district within the basin to the district as a whole, the total population of the basin is 6.83 millions. The State-wise distribution is shown on page 80.

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*Census Paper 1 of 1971 (Supplementary), Registrar-General (India).

Madhya Pradesh	1.66 millions
Uttar Pradesh	3.33 „
Bihar	1.84 „
Total	6.83 millions

The density of population in the basin is 239 persons per sq. km. The districts in Madhya Pradesh have lower densities than the average. In Uttar Pradesh the highest density of population is in Varanasi district which has 566 persons per sq. km. The lowest density is in the Panna district of Madhya Pradesh which has 60 per sq. km.

Of the total population, 84.4% lives in rural areas and the balance of 15.6% in urban areas.

There is no town having population of more than one lakh. Of the total population, 33.3 per cent is the working force, 51.1 per cent of which is engaged as cultivators, 26.5 per cent as agricultural labourers and the balance in other services.

Forests and Agriculture

4.18 Forests constitute about 18.2 per cent of the total geographical area. However the area under forests in the districts of Allahabad and Banda is quite low. In Allahabad it is as low as 2 per cent. In Sidhi and Panna districts more than 50% and 35% respectively of the geographical area are under forests.

Agriculture is the most important occupation of the people in the basin, engaging more than 75 per cent of the total working force. In the Tons sub-basin, agriculture mostly depends on rainfall. Irrigation is provided to only about 9 per cent of the area cultivated. In the Karamnasa sub-basin, the picture is totally different and nearly 52 per cent of the area under cultivation has irrigation.

Power

4.19 According to the surveys conducted by the Central Water and Power Commission, the hydro-power potential in the basin is 90 MW at a 60 per cent load factor. So far no power projects have been undertaken.

Mineral Wealth

4.20 The minerals found in the basin are: *

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*Techno-Economic Surveys of Bihar, Madhya Pradesh and Uttar Pradesh — NCAER.

Diamonds: In the Panna district, 50 per cent of the output being industrial diamonds. The reserves in 1,940 sq. km. of the area around Panna are considered to be substantial.

Corumdum: In the Rewa and Sidhi districts of Madhya Pradesh and Mirzapur and Banda districts of Uttar Pradesh.

Fire & China Clays: In the Satna district of Madhya Pradesh and Mirzapur and Banda districts of U.P.

Lime Stone: In the Mirzapur district of Uttar Pradesh, Rewa and Satna districts of Madhya Pradesh and Shahabad district of Bihar.

Industries

4.21 There is hardly any major industry situated in the basin except for some woollen mills in Mirzapur. Agriculture is the most important occupation and small industries making vegetable oil, soap, tobacco etc. and based on agricultural produce are to be found in the bigger towns.

Communications

4.22 The basin is served by the Northern and Central Railways. National Highways No. 7 and 27 pass through the basin. Though important towns and cities are connected by road and railway, it can be said that the hilly and interior areas of the basin are ill served by either good, all-weather roads or railways. The Tons, the Karamnasa and other rivers are not navigable.

WATER RESOURCES

Surface Water

4.23 The surface water potential of the basin had been assessed first in 1960 when the irrigation potential studies of the country were made by the Central Water and Power Commission. The annual run-off of the basin was assessed as 14,123 m. cu. m., on the basis of Strange's coefficients.*

Sufficient gauge and discharge data is not available for assessing the runoff in the basin. There is one Gauge-discharge silt observation site on the Tons at Meja Road.

Ground Water

4.24 The possibility of development in the Vindhyan regions is rather limited. However, the plains of Allahabad, Varanasi, Ghazipur, Mirzapur and Shahabad hold good prospects of ground waters.* In the Allahabad district, ground water occurs both in the alluvium and the hard rock regions. The near surface ground water occurs under water-table conditions while the deeper ground water under confined conditions. Tubewells constructed to a depth of 120 m. yield 100,000 to 160,000 litres per hour.

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*Report of the technological possibilities of irrigation projects in India, Central Water & Power Commission (unpublished).

In the Ghazipur district, ground water occurs both under water-table and confined conditions. Tubewells constructed to depths of 75 to 100 m. yield 45,400 to 172,520 litres per hour.

The greater part of the Mirzapur district is underlain by hard rocks belonging to Vindhyans and Gondwanas and a small strip of the district lies in the Gangetic alluvium. Tubewells drilled in the alluvial strips yield up to 125,000 litres per hour.

The greater part of the Varanasi district is underlain by quaternary alluvium. Tubewells yield up to 25,000 litres per hour.

In the Shahabad district ground water occurs under water-table conditions. Depth of water ranges from 2 to 8 m. in winter and 4 to 12 m. in summer. Heavy duty tubewells are normally employed for irrigation purposes.

EXISTING DEVELOPMENT

4.25 Before Independence there was hardly any irrigation in the basin. There was no major or medium project in either Madhya Pradesh or Bihar regions and only the Ghagar and Darai Canal in the Mirzapur district of Uttar Pradesh. The latter scheme consisted of a reservoir across the Ghagar river (a tributary of Son) and a canal system to irrigate lands in the Belon valley (a tributary of the Tons). A weir across the Karamnasa was constructed to divert its waters to make up for the shortage of water in the Ghagar reservoir. This scheme which was completed during 1914–17, irrigates 39,300 hectares.

Another earlier project is the weir across the Karamnasa viz. Latifshah weir constructed to irrigate small areas in Varanasi district. This system has been substantially expanded during the Plan periods by the construction of reservoirs across the Karamnasa and its tributaries and the extension of the canals.

In the Plan periods, systematic efforts have been made to develop irrigation in the basin and a number of irrigation schemes have been and are being executed. The more important of them are (i) Belan-Tons

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*Ground Water Resources of India, Status and Surveys, Prospects and Perspectives, Geological Survey of India (August, 1970).

Canal Scheme, (ii) Meja Reservoir, (iii) Nagwa Dam, (iv) Naugarh Dam and (v) Ahraura Dam.

4.26 The Tons-Belan Canal Project consists of a reservoir across the Bukkar nadi—a tributary of the Belan and a pick-up weir at Baranudha on the Belan about 40 km. downstream. The canal system starts from this point and irrigates 41,080 hectares in the Mirzapur district. The project was completed in 1961.

4.27 The Meja Reservoir is an extension of the Tons-Belan Canal Project. The project consists of a reservoir across the Belan river (tributary of the Tons) is situated upstream of the pick-up weir at Baranudha. The Belan Canal System is extended beyond the Tons and covers the area between the Tons and the Ganga in the Allahabad district. The area irrigated under this project is 21,190 hectares. The scheme was completed in 1966.

4.28 The Nagwa Dam constructed across the Karamnasa upstream of the Silhad Weir feeds into the Ghagar Canal System and provides irrigation to an additional area of 37,240 hectares. The Naugarh, the Ahraura and the Chandra Prabha dams provide irrigation in the Varanasi and Ghazipur districts.

4.29 The Uttar Pradesh Government has also undertaken two schemes viz., the Bhopauli Pumped Scheme and the Zamania Pumped Scheme to pump Ganga waters so as to increase the areas irrigated in the Karamnasa basin. The Bhopauli Pumped Scheme envisages the pumping of 10.19 cumecs from the Ganga to feed the Dhanpur Distributary ex-Ahraura and Jirgo reservoirs. The increased supply of water will help in extending irrigation to an additional area of 24,300 hectares under the system. Similarly the Zamania Pumped Scheme also envisages the pumping of 10.19 cumecs of the Ganga waters to feed the Chandauli Canal ex-Latifshah Weir and increase irrigation to an equal extent.

4.30 Another major pumped scheme undertaken by the Uttar Pradesh Government is the Tons pumped canal, envisaging the pumping of 16.99 cumecs from the Tons river in the Allahabad district. The increased supply will help the extension of irrigation to 52,650 hectares under the Belan and Tons Canal System.

4.31 In Bihar, two schemes, namely the Durgawati and the Kohira have so far been completed and one scheme viz., extension of irrigation from Musakhand Dam (Uttar Pradesh) is in progress.

4.32 The Musakhand Project is an important inter-state project constructed across the Karamnasa. Agreement has been reached between Uttar Pradesh and Bihar, for sharing the waters of the Karamnasa at the dam site (after allowing for existing utilisation). According to the agreement, the available water is 148.66 m. cu. m. of which 84.95 m. cu. m. will be for Uttar Pradesh and 63.71 m. cu. m. for Bihar. Agreement has also been reached regarding sharing of the cost. The work on the dam (situated in Uttar Pradesh) has been completed while the canal which has to be constructed in Bihar has been taken up during the Fourth Plan.

4.33 In Madhya Pradesh also, a number of medium schemes have been taken up in the Tons sub-basin to provide irrigation in the Rewa, Satna and Panna districts. The more important of them is the Gurmanala irrigating 7,690 hectares. Others irrigate less than 4,040 hectares.

4.34 Details of all the projects (including pre-plan schemes) undertaken in these river systems up to 1968–69 are given below:

Table 4.5

Projects Completed and Under Construction in the Basin

Name of Project	Location (District)	Date of completion	Estimated cost (Rs. million)	Ultimate irrigation (hectares)	Remarks
1	2	3	4	5	6
Madhya Pradesh					
(a) Pre-Plan Projects			NIL		
(b) Plan Projects					
(i) Completed Projects					
Kulgarhi Canal	Satna	1968-69	7.75	2,100	
Devendranagar	Panna	1968-69	6.34	2,430	
(ii) Projects Under Construction					
Gurmanala	Rewa	1974	9.29	7,690	
Raigwan	Satna	IV Plan	6.34	3,400	
Parreri*	Panna				*Dropped by the State
	Total (M.P.)		29.91	15,620	

Table 4.5—contd.

1	2	3	4	5	6
Uttar Pradesh					
(a) Pre-Plan Projects					
Ghagar and Darai Canal	Mirzapur		16.70	39,300	
(b) Plan Projects					
(i) Completed Projects					
Shahganj Distributary	Mirzapur	1955-56	2.29	8,070	
Nagwa Dam	,,	1956-57	8.34	37,240	
Chandraprabha	Varanasi	1956-57	8.54	37,240	
Naugarh Dam	Varanasi Ghazipur	1956-57	13.61	34,800	
Belan Tons Canal	Mirzapur	1961	24.73	41,080	
Meja Reservoir	,,	1965-66	33.40	21,190	
Jirgo Reservoir	,,	1961-62	12.52	25,900	
Upper Khajuri Reservoir	,,	1961-62	3.26	7,280	
Musakhand	Varanasi	1967-68	31.50	16,600	
Ahraura Dam	Mirzapur	1955-56	6.55	8,870	
(ii) Projects under construction					
Zamania Pumping Scheme	Ghazipur	IV Plan	11.80	24,300	
Bhopauli Pumping Scheme	Varanasi	,,	10.60	24,300	
Tons Pumped Canal	Allahabad	,,	17.50	52,650	
	Total (U.P.)		201.34	355,740	
Bihar					
(a) Pre-Plan Projects			NIL		
(b) Plan Projects					
(i) Completed Projects					
Durgawati	Shahabad	1957	3.67	10,520	
Kohira	,,	1966	5.68	10,320	
(ii) Projects under construction					
Karamnasa Canal	,,	V Plan	17.93	11,730	
	Total (Bihar)		27.28	32,570	
	GRAND TOTAL		258.53	403,930	

Source: Volume of Irrigation Chapter, Madhya Pradesh and Uttar Pradesh, Central Water and Power Commission (March, 1970).

4.35 When all the projects so far undertaken are completed, the total area irrigated from all major and medium projects will be of the order of 0.4 million hectares against the area of 0.24 million hectares irrigated at present. Of this, total irrigation of 48,600 hectares proposed under Zamania and Bhopauli Pumped Schemes will use waters of the Ganga though the command lies in the Karamnasa sub-basin. There is also considerable irrigation under tubewells. The areas irrigated in the basin (1967–68) under various sources like canals, tanks, tubewells etc. are given below:

Table 4.6

Source-wise Irrigation in the Basin

(Thousand hectares)

Source of irrigation	Area irrigated			
	Madhya Pradesh	Uttar Pradesh	Bihar	Total
1	2	3	4	5
Canals	2.00	65.30	144.50	211.80
Tanks	0.20	4.40	19.10	23.70
Wells (Tubewells included)	1.30	94.10	33.30	128.70
Other sources	0.40	10.90	18.10	29.40
Total	3.90	174.70	215.00	393.60

Irrigation in Madhya Pradesh is hardly 4,040 hectares. In Bihar, most of the area irrigated under canals is from the Son Canals. Only two projects namely, the Durgawati and the Kohira having total irrigation of 20,840 hectares have been completed, whereas total irrigation under canals in the district lying in the basin is 132,120 hectares.

As stated earlier, a total area of about 0.4 million hectares will be provided with irrigation when all the projects so far taken up are completed. Of this, 0.05 million hectares (under Zamania and Bhopauli Pumped Schemes) get supplies from the Ganga. The area utilising the waters of the Tons and Karamnasa basins will be 0.35 million hectares. According to data available, the average delta for projects in Uttar Pradesh is 0.73 m. and 1.2 m. in Bihar. Giving proper weightage for areas in each State, an overall delta of 0.76 m. may be assumed for all projects utilising the waters of the Tons and the Karamnasa. On this assumption, the quantity of water diverted for irrigating 0.35 million hectares will be of the order of 2,714 m. cu. m.

No data is available regarding water utilisation under minor irrigation works. The area irrigated by minor schemes in 1968–69 was of the order of 0.21 million hectares. With the same delta of 0.76 m. the utilisation by the minor schemes works out to 1,590 m. cu. m.

Reservoir Losses

4.36 On the basis of assumptions detailed in para 1.33 the reservoir losses from the various schemes in the basin will be as under:

(i) Major and Medium Schemes	387 m. cu. m.
(ii) Minor Schemes (tanks)	254 m. cu. m.
Total	641 m. cu. m.

4.37 Thus the annual utilisation (including reservoir losses) under all schemes so far undertaken would be:

	Canal diversion	Reservoir losses	
Major and medium schemes	2,714 m.cu.m.	387 m.cu.m.	
Minor schemes	1,590 ,,	254 ,,	
Total:	4,304 ,,	+ 641 ,,	=4,945 m.cu.m.

(3,819 m.cu.m. surface water+1,126 m.cu.m. ground water).

At present there are not many industries in the basin. However, the needs of industries that may come up in the future will have to be kept in view.

FUTURE DEVELOPMENT

4.38 There is only one scheme in the basin namely the Adwa Dam on the Tons, investigated and proposed by Uttar Pradesh. The project when implemented, is expected to provide irrigation to about 10,000 hectares. Other States have neither investigated nor proposed any scheme in the basin.

FLOODS, WATERLOGGING AND DRAINAGE

4.39 There is no serious flood problem in any of the rivers. Both the Tons and the Karamnasa have considerable catchment areas in the hilly terrain of Madhya Pradesh and Mirzapur district of Uttar Pradesh and flow within well defined banks. It is only when they start flowing in the plains before joining the Ganga, that these rivers spill their banks. However the flood problem has never been serious.

4.40 Waterlogging and drainage problems have not been reported in any of the irrigation systems situated in the basin.

SOIL CONSERVATION

4.41 Soil erosion is not a serious problem in the basin. The concerned State Governments have been undertaking soil conservation measures in the basin lying within their respective territories. A Centrally sponsored soil conservation scheme for the Mirzapur area has been undertaken. As a part of this scheme, contour and marginal bunding and check dams for arresting gully erosion have been suggested.

SALIENT FEATURES OF THE BASIN OF GOMATI, GHAGHARA AND OTHER RIVERS BETWEEN THEM

(i) Source:	The Gomati	Near Mainkot in the Pilibhit district of Uttar Pradesh (Latitude 28°34′N, Longitude 80°7′E).	
	The Ghaghara	About 40 km. south-west of Mansarowar in the Himalayan glaciers. (Latitude 30°38′N, Longitude 80°57′E).	
	The Chhoti Sarju	About 24 km. south-west of Faizabad in Faizabad district of U.P. (Latitude 26°41′N, Longitude 82°0′E).	
	The Besu	In the Jaunpur district of U.P. (Latitude 25°57′N, Longitude 82°42′E).	
	The Gangi	Near the border of the Jaunpur and Azamgarh districts of Uttar Pradesh. (Latitude 25°49′N, Longitude 82°46′E).	
(ii) Length:	The Gomati	940 km.	584 miles
	The Ghaghara	1,080 km.	671 miles
	The Chhoti Sarju	304 km.	189 miles
	The Besu	124 km.	77 miles
	The Gangi	90 km.	56 miles
(iii) Drainage area:	Uttar Pradesh	98, 127 sq. km.	37,887 sq. miles
	Bihar	3,000 sq. km.	1,158 miles
	Total	101,127 sq. km.	39,045 sq. miles
(iv) Population (1971 Census)		36.29 millions	
(v) Density of population		359 per sq. km.	930 per sq. mile
(vi) Maximum discharge	The Ghaghara	28,317 cumecs	1,000,000 cusecs
(vii) Minimum discharge:		N.A.	
(viii) Average annual runoff		122,793 m.cu.m.	99.55 MAF

		Thousand hectares	Thousand acres
(ix) Culturable area (1967-68)		7,686	18,993
(x) Net area sown (1967-68)		6,508	16,081
(xi) Gross area sown (1967-68)		8,516	21,044
(xii) Net area irrigated (1967-68)		2,143	5,295
(xiii) Gross area irrigated (1967-68)		2,248	5,555
(xiv) Ultimate irrigation by major and medium projects under operation & construction in 1968-69		1,577	3,897
		m.cu.m.	MAF
(xv) Water utilisation, including reservoir losses on completion & full development of major, medium and minor projects under operation & construction in 1968-69	Surface water	21,280	17.25
	Ground water	13,186	10.69
	Total	34,466	27.94

CHAPTER V

BASIN OF GOMATI, GHAGHARA AND OTHER RIVERS BETWEEN THEM

The Gomati, the Ghaghara and other rivers flowing between them can be considered together, as the water resources development in these sub-basins are inter-connected. In fact, the waters of the Sarda, one of the tributaries of the Ghaghara has been mainly responsible for all the irrigation development in the area between the Ramganga on the west, the Great Gandak on the east, the Tarai region of Nepal on the north and the Ganga on the south.

The Basin

5.2 The basin, in Indian territory, extends over an area of 101,127 sq. km., which is nearly double the area of Punjab and lies between east longitudes 79°27′ to 84°58′ and north latitudes **25°25′** to 30°39′. Lying to the north of the Ganga, the basin covers a large areas in the State of Uttar Pradesh and a small area in Bihar. The State-wise distribution of the drainage basin is given below:

Uttar Pradesh	98,127 sq. km.
Bihar	3,000 ,,
Total	101,127 sq. km.

5.3 The basin is bounded on the north by the Himalayas, on the east by the ridge separating it from the Gandak basin, on the south by the Ganga river and on the west by the ridge separating it from the Ramganga basin. It is roughly rectangular in shape with a maximum length of 730 km. in the NW-SE direction and a maximum width of 370 km. in the NE-SW direction.

THE RIVER SYSTEM

5.4 The Gomati rises near Mainkot, about 3 km. east of Pilibhit town in the Pillibhit district of Uttar Pradesh at an elevation of 200 m. at north latitude 28°34′ and east longitude 80°7′ and drains the area lying between the Ramganga and the Sarda in the upper reaches and lower down the area between the Ganga and the Ghaghara. After flowing in a southerly course for a distance of about 24 km., it receives its first tributary the Gachai. Flowing through the Shajahanpur district for a total length of 56 km., the Gomati receives two more tributaries namely the Jomkai and the Barua. Running through the Kheri and the Lucknow districts, the river receives two more small tributaries, namely the Chuha on its right bank and the Sarayan on its left bank. The river flowing in a south-easterly direction passes through Lucknow. Leaving the Lucknow district, the river flows through the districts of Barabanki, Sultanpur, Faizabad and Jaunpur and finally before its confluence with the Ganga forms the boundary between the Varanasi and Ghazipur districts. The total length of the river is about 940 km. and the river drains a total area of 30,433 sq. km. From the origin to its confluence, the river flows entirely in the State of Uttar Pradesh.

5.5 The Sai is the most important tributary of the Gomati joining on its right bank. It rises in Hardoi district and traverses the districts of Raibareli and Pratapgarh and forms the boundary between the Lucknow and Unnao districts. Subsequently it flows through Jaunpur district before joining the Gomati about 60 km. upstream of the confluence of the latter with the Ganga. The Sai river has a drainage area of 11,115 sq. km.

5.6 *The Ghaghara* known variously as the Sarju and the Dehwa contains the combined waters of the Chauka or Sarda and the Kauriala which unite near Bahramghat in the Barabanki district of Uttar Pradesh. The Ghaghara is a mighty river with a considerable Himalayan catchment. Part of its catchment lies in Nepal. Out of a total catchment area of 127,950 sq. km., the area lying in Indian plains is only 57,647 sq. km. while the balance lies in the Himalayas and Nepal.

The Karnali or the Manchu as the Ghaghara is called in upper reaches has its source in the Himalayan glaciers about 60 km. south-west of Mansarowar at an elevation of 4,800 m. at north latitude 30°38′ and east longitude 80°57′. After flowing for about 72 km. in a south-easterly direction, the river enters Nepal territory. The river continues its serpentine course and receives the Mugu Karnali and the Tila on its left bank. After flowing for another 25 km. below its junction with the Tila, the river takes a winding course till Churighat whereafter it takes almost a westerly course till it reaches Dundras. At this point the river takes a 'U' turn and starts flowing in a southeasterly direction till it debouches into the plains of Nepal after passing through a narrow gorge in the Siwalik range of hills. In this reach, the river is joined by two more tributaries viz., the Seti on its right bank and the Boeri on its left.

As the river enters the plains, it divides into several channels, the more important of which are the Kauriala and the Girwa. The Kauriala before leaving Nepal receives the Mohan river on its right. Both the Kauriala and the Girwa rejoin at Bharatpur in the Bahraich district of Uttar Pradesh. The river bed from this point onwards is sandy and its course is liable to abrupt changes. Near Gularia the river receives the Sarju on its right and further downstream the Baberi Sarju on its left. The Sarda or Chauka the most important tributary of the Ghaghara joins the Kauriala at Rampur Mathura.

After the junction with the Sarda, the river is known as the Ghaghara and flows in a generally south-easterly direction. Earlier it forms the boundary between the Bahraich and Gonda districts and later between the Barabanki and Gonda districts. The Lower Sarju and the Tirhi rivers join the Ghaghara in the Gonda district. During its course through Gonda district, the river inundates a large area on its left by spilling its flood water into the rivers Sarju, Tirhi etc., which join the river on its left bank. The Tirhi joins the Ghaghara near Nawabganj. About 19 km. below its junction with the Tirhi, the river flows by Ayodhya. It then forms the boundary between the Faizabad and Ballia districts and flows in continually shifting channels within a broad sandy bed about 6 km. in width. During the monsoons it carries an enormous volume of water.

Flowing through the districts of Gorakhpur, Deoria, Azamgarh and Ballia, the river has the characteristics described earlier. Even during the winter, it flows in more than one channel. The entire area on the right of the Ghaghara in the Azamgarh and Ballia districts is liable to inundation from floods. The country here has innumerable long narrow lakes which are really old beds of rivers. Near Dhuriapar, the Kuwano river joins the Ghaghara on its left. The course of the Ghaghara is confined to a single channel at Dohrighat where Kankar reefs appear. Elsewhere the banks consist of soft sandy alluvial deposited by the river itself. The width of the valley varies and is sometimes as much as 16 km. To the east of Dohrighat, the river again splits into two channels. The main channel of the river flows to Barhaj town and about 5 km. west of Barhaj, the Rapti river joins from the left. The Ghaghara is joined on its left bank by the little Gandak about 3 km. south of Gothini village where it forms the boundary between Bihar and Uttar Pradesh. After receiving the Jhorahi and the Daha, two small rivers on its left, the river finally joins the Ganga a few kilometres downstream of Chapra in Bihar.

The Ghaghara flows for a total length of about 1,080 km., the upper half of which lies in Nepal and the lower half in Uttar Pradesh.

The most important tributaries of the Ghagara are the Sarda, the Rapti and the Little Gandak.

5.7 *The Sarda* is formed by two streams the Kuthiayankti and the Kalapani near the Indo-Tibet border at an elevation of 5,250 m. at north latitude 30°28′ and east longitude 80°35′. The river flows in a southwesterly direction for some distance forming the boundary between India and Nepal. In this reach it receives the Dhauli Ganga, the Khoprang, the Sarju and the Ladhiya on its right and the Chumlia on its left. It debouches into the plains of Uttar Pradesh after passing through a series of rapids.

Entering the plains, the Sarda continues to form the boundary between India and Nepal for a short distance flowing in a boulder bed. Thereafter it flows in a southeasterly direction through the district of Pilibhit in a tortuous and constantly changing course. The river bed consists of sand and mud. The river banks are friable and it has no difficulty in carving out fresh channels from time to time. During high floods large areas are inundated by the waters of the Sarda. One of the most important irrigation systems in Uttar Pradesh irrigating lands in the Gomati-Ghaghara doab emanates from this river from the Banbassa head works.

5.8 *The Rapti* is another important tributary of the Ghaghara to join on its left bank. It rises in the lower ranges of Nepal at an elevation of 3,600 m. at north latitude 28°22′ and east longitude 82°56′ and after flowing through Nepalese territory for a distance of about 150 km., it enters the Bahraich district of Uttar Pradesh. It then flows in a southeasterly direction through the districts of Gonda, Basti and Gorakhpur before joining the Ghaghara near Barhaj in the last named district. Its wide bed is confined within high banks but the actual channel shifts considerably between the two banks. The Rapti also inundates large territories on both its banks. Though flooding temporarily dislocates life in these territories, it is beneficial because of the fine silt left behind which makes the land fertile and productive.

5.9 *The Little Gandak* represents an old channel of the Great Gandak. Starting in the Baghban forest in Nepal at an elevation of 300 m. at north latitude 27°36′ and east longitude 83°46′, it flows in a southeasterly direction and joins the Ghaghara near Simiria in the Shahjahanpur district. Except in the monsoon season, the Little Gandak carries very little discharge.

Minor Basins

5.10 *The Chhoti Sarju,* a tributary of the Ganga drains the eastern districts of Uttar Pradesh between the Ghaghara and the Gomati. It rises from a tal situated about 24 km. south-west of Faizabad at an elevation of 100 m. at north latitude 26°41′ and east longitude 82°0′ and flows almost parallel to the Ghaghara river. It flows through Azamgarh and Faizabad districts and joins the Ganga 5 km. to the west of Ballia town.

5.11 *The Besu* is a small river having its origin in the Jaunpur district of Uttar Pradesh at an elevation of 90 m. at north latitude 25°57′ and east longitude 82°42′. Its drainage area lies wholly in the plains and the river joins the Ganga near Ghazipur town after flowing through the districts of Jaunpur, Azamgarh and Ghazipur.

5.12 *The Gangi* river rises near the border of the Jaunpur and Azamgarh districts at an elevation of 90 m. at north latitude 25°49′ and east longitude 82°46′. It flows in a south-easterly direction parallel to the Besu river and joins the Ganga about 8 km. west of Ghazipur.

CLIMATE

5.13 Except in the hilly regions in the northern parts of Uttar Pradesh, the climate is mostly tropical with high temperatures in summer generally of the order of 42–44°C. The minimum temperatures in winter are as low as 1°C. The summer is mostly dry with the very little humidity. The basin receives most of its rainfall during the south-west monsoon i.e. from June to September. The average annual and monsoon rainfalls in various districts lying within the basin are given below:

Table 5.1

Rainfall in the Basin

Name of District	Average annual rainfall in mm.	Monsoon rainfall in mm.
1	2	3
Uttar Pradesh		
Kheri	1,069	922
Sitapur	974	850
Bahraich	1,148	995
Gonda	1,150	1,012
Barabanki	1,003	883

Table 5.1—contd.

1	2	3
Basti	1,264	1,100
Deoria	1,145	988
Ballia	1,013	892
Gorakhpur	1,364	982
Faizabad	1,008	891
Pilibhit	1,242	1,085
Almora (av.)	1,543	
Nainital	1,566	1,386
Ghazipur	1,052	926
Azamgarh	1,021	900
Jaunpur	1,000	886
Sultanpur	1,000	887
Shahjahanpur	1,020	891
Hardoi	879	772
Lucknow	859	849
Unnao	838	742
Raibareli	928	825
Varanasi	1,056	926
Allahabad	976	865
Pratapgarh	978	869
Bihar		
Saran	1,121	971

Source: IMD—Monthly and annual normals of rainfall and of rainy days (1901-50).

5.14 There are in all 65 rain gauge stations in the Ghaghara basin (including 14 numbers in the Trans-Himalayan region) giving an average dispersion of one rain gauge for every 887 sq. km. The distribution of the stations is not even and their number is also not sufficient. It is suggested that a few more raingauges to obtain a balanced distribution over the entire basin should be established.

There is one departmental and one agro-meteorological observatory of the Indian Meteorological Department within the basin.* The departmental observatory is located at Lucknow and the agro-meteorological observatory at Basti.

SOILS

5.15 No detailed soil survey of the basin has yet been made. However, the general data regarding the soils of India indicates that mainly alluvial, calcareous alluvial, terai and brown hill soils occur in the basin. The principal soil types found in the various districts lying in the basin are given below:*

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* Evaporation Data (India), India Meteorological Department (April, 1970).

Table 5.2

Soils in the Basin

District	Type of soil
1	2
Uttar Pradesh	
Kheri	Alluvial and terai
Sitapur	Alluvial
Bahraich	Alluvial and terai
Gonda	Alluvial and terai
Barabanki	Alluvial
Basti	Alluvial, calcareous alluvial and terai
Deoria	Alluvial and calcareous alluvial
Ballia	Alluvial
Gorakhpur	Calcareous alluvial and terai
Faizabad	Alluvial
Pilibhit	Alluvial and terai
Almora	Brown hill
Nainital	Alluvial, terai and brown hill
Ghazipur	Alluvial
Azamgarh	Alluvial
Jaunpur	Alluvial
Sultanpur	Alluvial
Shahjahanpur	Alluvial
Hardoi	Alluvial
Lucknow	Alluvial
Unnao	Alluvial and saline
Rae Bareli	Alluvial
Varanasi	Alluvial and red and yellow
Allahabad	Alluvial and red and yellow
Pratapgarh	Alluvial
Bihar	
Saran	Alluvial and calcareous alluvial

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* Indian Crop Calendar, Ministry of Food, Agriculture, Community Development and Cooperation (1967).

LAND USE AND AGRICULTURAL PRACTICES

5.16 Land use details in the basin for the year 1967–68 are given below:

Table 5.3

Land Use Details

(Thousand hectares)

Item	STATE		
	Uttar Pradesh	Bihar	Total
1	2	3	4
Geographical area	9,813	300	10,113
Reporting area	9,767	300	10,067
Area under forests	671	—	671
Area not available for cultivation	1,666	44	1,710
Culturable area	7,430	256	7,686
Uncultivated culturable area	1,133	45	1,178
Net area sown	6,297	211	6,508
Area sown more than once	1,924	84	2,008
Total cropped area	8,221	295	8,516
Net irrigated area	2,089	54	2,143
Gross irrigated area	2,191	57	2,248
Percentage of net area sown to culturable area	84.7	82.6	84.7
Percentage of net irrigated area to net sown area	33.2	25.4	32.9

Nearly 94% of the basin lies in the Gangetic Plains. About 76.3% of the area in the basin is culturable and of the culturable area of 7.69 million hectares, 6.51 million hectares i.e. nearly 84.7% are cultivated annually.

5.17 Irrigation has long been practised in the basin. With the inception of the Sarda Canal in 1926, irrigation has been provided over large areas. The Sarda Canal has been improved and extended during the Plan periods by a number of projects executed in the basin. At present more than 30% of cultivated area has irrigation.

As in other parts of India, agriculture—whether under irrigated or unirrigated conditions in the basin, is dominated by food crops. Practically the entire area is under food crops. Rabi crops like wheat, barley and pulses dominate the cropping pattern. The details of the irrigated crops during 1967–68 are given in Table 5.4.

Table 5.4

Irrigated Crops During 1967-68

(*Thousand hectares*)

Name of crop	Uttar Pradesh		Bihar		Total for the basin	
	area	% age	area	% age	area	% age
1	2	3	4	5	6	7
Rice	89.9	4.1	2.8	4.8	92.7	4.1
Wheat	881.3	40.2	23.5	40.9	904.8	40.3
Barley	471.9	21.5	17.4	30.2	489.3	21.8
Pulses	100.1	4.6	2.1	3.6	102.2	4.5
Sugarcane	205.9	9.4	1.1	2.1	207.0	9.2
Other food crops	423.7	19.4	9.4	16.3	433.1	19.3
Total food crops	2,172.8	99.2	56.3	97.9	2,229.1	99.2
Non-Food crops	18.1	0.8	1.2	2.1	19.3	0.8
All crops	2,190.9	100.0	57.5	100.0	2,248.4	100.0

Crop Seasons

5.18 The main crop seasons are the kharif and the rabi. The kharif season begins with the onset of the south-west monsoon in June and extends up to October. The Rabi season lasts from November to March-April. The crop pattern is dominated by the rabi crops.

REGIONAL ECONOMY

Population

5.19 On the basis of the 1971 Census* and the percentage of the area of each district within the basin to the district as a whole, the total population in the basin is about 36.29 million of which nearly 34.44 million live in Uttar Pradesh and the rest in the Saran district of Bihar. Saran district is the most densely populated area in the basin with 620 persons per sq. km. while Almora has the lowest density with 75 persons per sq. km. The average density of population in the basin is 359 per sq. km. against a figure of 182 for India as a whole.

5.20 There are two cities within the basin having a population of more than one lakh. These are Lucknow, the Capital of Uttar Pradesh and

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* Census Paper I of 1971 (Supplementary), Registrar-General (India).

Gorakhpur also in Uttar Pradesh. The main occupation of the people is agriculture and more than 93 per cent of the total population live in villages. 32.1 per cent of the total population is the working force of which nearly 50.7 per cent are cultivators and about 26.6 per cent work as agricultural labourers. The remaining 22.7 per cent of the working force are employed in other services.

Forests and Agriculture

5.21 Except in the higher reaches lying in Nainital and Almora districts, practically the entire basin lies in the Gangetic plain and is culturable. Forests occupy only 6.66 per cent of the total area of the basin. The culturable area constitutes nearly 76.3 per cent of the total area of the basin. Out of a total culturable area of 7.7 million hectares nearly 84.7 per cent i.e. 6.5 million hectares are cultivated annually. A characteristic feature of the basin is that practically the entire cultivated area is under food crops. Another feature is that nearly 32.9 per cent of the cultivated area has irrigation. Rabi crops dominate the agriculture pattern in the basin. Wheat constitutes the main crop among irrigated crops and occupies nearly 40.3 per cent of the total area irrigated. Barley and gram occupy second place with 26.3 per cent of the total irrigated area.

Power

5.22 The Ghaghara sub-basin has a very rich hydro-power potential. According to the surveys conducted by the Central Water and Power Commission, the total hydro-power potential in the basin has been assessed as 4,587 MW at 60 per cent load factor. Of this, the potential of the Karnali (Ghaghara in Upper reaches) accounts for 2,550 MW and of the Sarda for 1,942 MW. So far no power has been developed from these sources.

Mineral Wealth

5.23 The basin has poor mineral wealth. It is practically devoid of any minerals except limestones which occurs in the form of marls in the Lucknow, Raebareli, Unnao and Barabanki districts.*

Industries

5.24 Due to the lack of mineral resources, development of industries has lagged and the most important occupation of the people in the basin is agriculture. Even the few industries which exist in the basin are based either on agriculture or on forest produce. Textile mills and paper mills in Lucknow and jute textiles in Gorakhpur can be mentioned. In and around Lucknow city light industrial units, pharmaceutical and chemical industries, glass and glassware industries, are situated.

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* Techno-Economic Survey of Uttar Pradesh, NCAER.

Communications

5.25 The basin is well served by railways. The broad gauge-lines from Delhi to Lucknow, Lucknow to Kanpur, Lucknow to Gorakhpur on the northern railway all pass through the basin. The basin is also well served by a number of National Highways, State Highways and district roads. The National Highways No. 25 (connecting Lucknow with Kanpur) and No. 29 (connecting Gorakhpur with Ghazipur) pass through the basin.

All the rivers in the plains are navigable. Small country craft ply on them carrying men and materials.

WATER RESOURCES

Surface Water

5.26 The surface water potential of the basin has been assessed at different times by different authorities. The very first assessment was made by the first Indian Irrigation Commission. As there were no records to show the surplus passing to the sea, reliance was placed upon a coefficient of run-off, selected with regard to the rainfall and other conditions, and to the coefficient of actual flow, determined for other catchments. The Commission, however, cautioned that the estimates arrived at by this method must be regarded as mere rough approximations. According to the above assessment, the total annual surface flow of the Ganga below Varanasi was estimated at 325,564 m. cu. m.*

In 1949 when the assessment of the basin-wise water resources of the country was made on the basis of Khosla's formula, the annual runoff of the Ganga between its confluences with the Yamuna and the Ghaghara, including the Ghaghara was estimated as 110,162 m. cu. m. The annual runoff of the Ghaghara was assessed at 75,760 m. cu. m.**

5.27 The CW & PC have estimated† the average annual runoff of the

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* Report of the Indian Irrigation Commission (1901-03).

** An appraisal of water resources by Dr. A. N. Khosla, UNESCO.

† Report of the technological possibilities of irrigation projects in India, Central Water and Power Commission (unpublished).

Gomati sub-basin as 8,462 m. cu. m. based on Strange's formula. Similarly the average annual runoff of the Ghaghara and other minor basins has been assessed as 114,331 m. cu. m. The break up is given below:

Ghaghara sub-basin		
(i) Himalayan	91,277	m. cu. m.
(ii) Plains	19,600	,,
Minor basins		
Choti Sarju	2,763	,,
Besu	432	,,
Gangi	259	,,
Total	114,331	m. cu. m.

(The yield in the Himalayan portion of the Ghaghara has been calculated on the basis of observed discharges for the years 1931–50 at Banbasa on the Sarda river while the other figures are based on Strange's formula).

Water potential of the entire basin works out to 122,793 m. cu. m.

5.28 The average yield of the Gomati sub-basin is 8,000 m. cu. m. and of the Ghaghara and other minor basins 83,000 m. cu. m.

5.29 The Sarda river has been gauged for a considerable length of time at the existing Banbasa Headworks. A number of Gauge Discharge Stations have been established on the Ghaghara, the Sarda and other tributaries since 1958.

Groundwater

5.30 The Gangetic plain in which most of the basin lies is known to be rich in groundwater resources. The Geological Survey of India have investigated the possibilities of groundwater resources development in various districts lying in the basin. Their findings are summarised below: *

In the Allahabad district, groundwater occurs both in the alluvium and hard rock. The near surface groundwater occurs under water table conditions while the deeper water occurs under confined conditions. Heavy duty tubewells are considered to be more appropriate for groundwater development in the district. Groundwater in the Azamgarh, Ballia and Ghazipur districts occurs both under water table and confined conditions.

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* Ground Water Resources of India, Status and Surveys, Prospects and Perspectives, Geological Survey of India (August, 1970).

The groundwater is found to be suitable for irrigation and heavy duty tubewells have been considered suitable for groundwater development in the region. In the Barabanki district, groundwater occurs both under confined and unconfined conditions. This area has also been considered fit for deployment of heavy duty tubewells. Groundwater in the Basti district occurs both under water table and confined conditions and is fit for irrigation.

The availability of groundwater in the Deoria and Gorakhpur districts is influenced by the presence of the Ghaghara and the Great Gandak. The water table is shallow in the vicinity of the Great Gandak river and progressively falls as one goes away from it.

Geohydrological studies carried out in the Faizabad, Raebareli and Varanasi districts indicate that near surface groundwater occurs under water table conditions while deeper aquifers occur under confined conditions. In the Unnao district groundwater occurs under water table conditions in the alluvium. Groundwater in the Gonda district occurs under water table as well as confined conditions.

Jaunpur and Lucknow districts are underlain by alluvial deposits comprising sand, clay and kankar. The water table in the Jaunpur district lies within 14 m. of the land surface and large scale development of groundwater by means of tubewells is feasible. In the Pratapgarh district an area of about 2,500 sq. km. has been studied for geohydrological conditions. The area is underlain by alluvium comprising sand gravel, clay and kankar.

Most of the districts lying in the basin have good possibilities of groundwater development by means of wells and tubewells. In the Gangetic plain considerable areas have been irrigated by groundwater. No quantatitive assessment of the groundwater is available.

EXISTING DEVELOPMENT

5.31 The waters of the Sarda have been used extensively for irrigation development in the basin. Practically all the irrigation in the Gomati-Ghaghara doab right up to the Ganga is from the Sarda. The Sarda Canal constructed between 1915-26 and subsequently improved and extended during plan periods irrigates nearly 0.8 million hectares in the basin.

5.32 Prior to Independence only two projects namely the Sarda Canal and the Gogra Canal (lift irrigation) were in existence in the basin.

Sarda Canal

5.33 The proposal for the construction of the Sarda Canal to irrigate nearly one million hectares of land lying between the Ghaghara and the Ganga was first made in 1870. Subsequently in 1871, it was revised to irrigate a restricted area of about 0.25 million hectares. The scheme was held in abeyance for a number of years due to opposition of the landowners. The first Indian Irrigation Commission examined the proposal and suggested detailed investigations. The Commission recognised the necessity of irrigation in the districts of Hardoi, Lucknow, Barabanki, Shahjahanpur, Unnao and Raebareli and also suggested that necessary provision for anti-waterlogging measures may be made in the project. The work on the Sarda Canal was taken up in 1915 and was completed in 1926. In 1951 this canal system irrigated an area of about 0.6 million hectares. Till recently, it was also supplying water for irrigating lands in the Ramganga basin. This area has now been covered by the Nanak Sagar Project, completed in 1963–64. The waters of the Sarda thus released have been made use of for extending irrigation in the Sarda command itself.

Ghaghara Canal

5.34 The Ghaghara Canal Project provides for the lifting of the water of the Ghaghara river to irrigate 17,680 hectares in the Faizabad district and has been existing since 1938.

The demand for water in the Sarda Canal has been steadily increasing and the Uttar Pradesh Government has taken up a number of schemes for supplementing the water supply. Schemes like the construction of a storage across the Sarda and the extension of the canal system have been undertaken. In addition, there are pumped canals irrigating considerable areas in the basin. These are the Dohrighat Pumped Canal (irrigating 48,080 hectares), the Tanda Pumped Canal (27,480 hectares) and the Kuwano Pumped Canal (8,590 hectares).

Recently the Uttar Pradesh Government has proposed the Sarju Canal Project for supplementing supplies from the Sarda Canal. The scheme envisages the construction of a barrage across the Ghaghara at Katarnia Ghat in the Bahraich district to carry the Ghaghara waters through a feeder canal to different branches of the Sarda Canal System, in the lower reaches. The project which is expected to be completed by the end of the Fifth Five Year Plan will bring an additional area of about 0.6 million hectares under irrigation in the Sarda Canal System.

Dalmau Pumped Canal

5.35 The scheme envisages the lifting of 23.79 cumecs of water from the Ganga near the village of Dalmau in the Raebareli district to feed the

Purwa branch of the Sarda canal through a feeder canal. 16 electric pumps each having a capacity of 1.70 cumecs will lift 23.79 cumecs of water from the river Ganga to feed it into the Sarda system. The scheme which is expected to be completed by the end of the Fourth Five Year Plan will bring an additional area of 62,330 hectares in the Raebareli district.

5.36 Details of the major and medium projects under operation and construction in the basin are given below:

Table 5.5

Projects Completed and Under Construction in the Basin

Name of Project	Location (District)	Date of completion	Estimated cost (Rs. million)	Ultimate irrigation (hectares)
1	2	3	4	5
Uttar Pradesh				
(a) **Completed Projects**				
(i) **Pre-Plan Projects**				
Sarda Canal	Nainital (benefits in other districts also)	1926	151.72	612,470
Gogra Pumped Canal	Faizabad	1938	5.17	17,680
(ii) **Plan Projects**				
Sarda Sagar Stage I & II	Pilibhit St. I St. II	1958-59 1961-62	48.00 73.22	67,740 74,930
Trans Kalyani	Barabanki	1960-61	5.72	19,060
Benganga Canal	Gorakhpur	1960-61	4.55	8,900
Pratapgarh Branch	Raebareli & Pratapgarh	1957-58	6.99	19,190
Dohrighat Pumped Canal	Azamgarh	1965-66	17.51	48,080
Tanda Pumped Canal	Basti	1962-63	8.58	27,480
Kuwano Pumped Canal	Gonda	1964-65	4.09	8,590
Jahangirganj Branch	Faizabad	1969	3.36	13,810
Total of completed projects			328.91	907,930

Table 5.5—contd.

1	2	3	4	5
(b) Projects under construction				
Sarda Assist Stage I (Improvement to the Sarda Canal System)	Bahraich (Benefits in the Sarda Canal System)	V Plan (Probable)	648.40	606,300
Dalmau Pumped Canal	Raebareli	IV Plan (Probable)	16.40	62,330
Total of projects under construction			664.80	668,630
Bihar			NIL	
Grand total			993.71	1,576,560

Note Volume on irrigation chapter for Uttar Pradesh, Central Water and Power Commission.

5.37 All the major and medium projects (including those in existence prior to the First Five Year Plan) so far undertaken will provide irrigation facilities to an area of 1.58 million hectares in the basin. In the above figure are included the benefits which would accrue from the Sarju Canal Stage I Project (606,300 hectares) and the Dalmau Pumped Canal Project (62,330 hectares) which are under construction. The irrigation facilities so far created from major and medium projects is of the order of 0.91 million hectares and area irrigated under these projects up to the end of 1968–69 was of the order of 0.9 million hectares.

5.38 In addition to the above major and medium projects, there are a good number of tanks, wells and tubewells providing irrigation to small areas under them. The source-wise irrigation in the basin during the year 1967–68 was as given below:

Table 5.6
Source-wise Irrigation

(Thousand hectares)

Source of Irrigation	Area irrigated Uttar Pradesh	Bihar	Total	Percentage to total area irrigated
1	2	3	4	5
Canals	406.4	0.1	406.5	19.0
Tanks	267.1	4.4	271.5	12.0
Wells (Tubewells included)	256.8	44.8	1,301.6	60.7
Other sources	158.5	4.5	163.0	7.6
Total:	2,088.8	53.8	2,142.6	100.0

Minor sources namely, tanks, wells, tubewells etc. irrigate a very large area in the basin. These account for nearly 81 per cent of the total area irrigated.

5.39 The average delta obtainable in the most important canal system in the basin viz., the Sarda Canal System is 0.91 metre. On this basis, the total water diverted for the entire area of 1.51 million hectares which is expected to be irrigated when all the projects so far undertaken are completed (excluding the area of 62,330 hectares to be irrigated from the Ganga waters under the Dalmau Pumped Canal Scheme), would be of the order of 13,815 m. cu. m.

In the absence of data regarding the delta obtainable under minor irrigation schemes, the delta obtained in the Sarda Canal System, has been adopted. The total area under minor schemes during 1968–69 was of the order of 1.92 million hectares. Water diverted under minor schemes would be of the order of 17,589 m. cu. m.

Evaporation Losses

5.40 Evaporation losses under major and medium storage schemes are of the order of 250 m. cu. m., on the assumption that they form 20% of the annual diversions. So far as minor irrigation schemes (tanks) are concerned, the Commission has assumed that the water spread of a tank would be about 7/8 (87.5%) of the area irrigated from it and that a total loss of 1.07 m. occurs over the water surface area for the period that the tank is full (from June to December approximately). On this basis, the losses under minor irrigation schemes work out to 2,812 m. cu. m.

5.41 Thus, on completion and full development the total annual utilisation from all major, medium and minor irrigation schemes under operation and construction in 1968–69 would be of the order of 34,466 m. cu. m. (21,280 m. cu. m. of surface +13,186 m. cu. m. of ground).

As stated in para 5.24 the activities in the basin are essentially agricultural and there are hardly any major industries. Although the water requirement of industries at present may be considered as insignificant, this aspect has to be kept in view while planning future projects.

FUTURE DEVELOPMENT

5.42 The water potential of the basin as assessed by the Central Water and Power Commission is of the order of 122,793 m. cu. m. The utilisation from all the projects which have so far been completed or are on hand will be of the order of 34,466 m. cu. m. This leaves an enormous quantity of water for future development.

5.43 The following are possible future projects in the basin:

Name of the Project	Area benefited in thousand hectares
Projects investigated	
Sarda Assist Project Phase I	621
Sarda Assist Project Phase II	552
Sarda Assist Project Phase III	285
Pancheswar Dam	809
Chisapani Dam	809
Gomati Pumped Canal	62
Projects to be investigated	
Azamgarh Pumped Canal	249
Shapur Weir	111
Other small projects	58
Total:	3,556

5.44 Of the projects listed above the Sarda Assist Phase I to provide irrigation facilities to 0.6 million hectares has already been taken up and is expected to be completed by the end of the Fifth Five Year Plan. Phase II and III of the project are yet to be taken up.

5.45 The Pancheswar Dam across the Sarda and the Chisapani across the Karnali (Ghaghara) are primarily power projects. However a large quantity of regulated releases would be available for irrigation also. Between them, the two projects are expected to generate power of the order of 1,100 MW. The Pancheswar Dam is to be located on the border of India and Nepal while Chisapani will be entirely in Nepal territory. These projects can therefore be taken up only with the concurrence of the Nepal Government.

5.46 When all the projects listed above (except the Sarda Assist Project Phase I which has already been accounted for in para 5.36) are implemented, an additional area of 2.95 million hectares would get irrigation facilities. The total water utilisation under these projects on an average delta of 0.91 m. as obtained in the existing Sarda Canal System will be of the order of 26,963 m. cu. m. (exclusive of storage losses).

It is thus clear that the basin will have a large quantity of surplus water even after all the future projects listed above are implemented.

FLOODS, WATERLOGGING AND DRAINAGE

5.47 The eastern districts of Uttar Pradesh which lie in the basin are perhaps the worst flood affected districts in the State. The Ghaghara, the Rapti and the Sarda are very big rivers with considerable portions of their catchment areas in the Himalayan region. These rivers have very high discharges. The maximum discharge of the Ghaghara for example goes up to 28,317 cumecs in its lower reaches. During their course in the Himalayas the rivers have steep slopes and carry huge quantities of silt and detritus. As they emerge into the plains, the slopes flatten out and consequently the detritus carried by them is deposited. This results in the constant shifting of the rivers and consequent inundation of vast areas. The Ghaghara, when it is in high flood, inundates an area of the order of 0.6 million hectares while the Rapti affects an area of nearly 0.3 to 0.35 million hectares. Though the Sarda in the upper reaches flows in a regular channel, it spills over its banks in the Kheri and Sitapur districts and inundates large areas.

Even the smaller rivers like the Gomati, the Sai and the Tons which rise in the plains cause considerable inundation in the areas through which they flow. The reasons attributed are the obstruction of waterways by habitation and cultivation, heavy rainfall in the plains and inadequate waterways provided for bridges across streams.

The first work to protect lands from floods in the basin was the Muloni Bund about 25 km. long which was constructed towards the end of the 19th century along the left bank of the Rapti to protect Gorakhpur town. Similar embankments were constructed on the left bank of the Tons to save Azamgarh town from floods.

Recently a number of works have been taken up in the basin for controlling inundation by the rivers. Important works are the Mohala-Gorakhpur and the Turtipur-Srinagar bunds along the Ghaghara, the Bohra Bahrauli bund and the Paraspur-Dhaura bund along the left bank of the Sarju. On the Rapti, embankments like the Maloni bund near Gorakhpur have been raised and strengthened. In the flood plains of the Ghaghara, the Rapti and the Ganga, a good number of villages have been protected from floods either by raising their plinths or by putting ring bunds around them or shifting them to higher ground. A large number of schemes for improving the drainage capacity of the existing channels and for increasing the waterway of bridges on smaller streams have also been taken up.

5.48 No information regarding waterlogging in the canal systems in the basin is available. Even when the Sarda Canal was being constructed there were misgivings about waterlogging problems that may arise because of canal irrigation. As the soils are mostly alluvial and the water table is fairly high in the region, great care is needed to avoid waterlogging in the canal command.

SOIL CONSERVATION

5.49 As already stated earlier, rivers like the Ghaghara, the Sarda and the Rapti bring down a deteritus from the Himalayas. This silt causes the shifting of the river courses and the consequent inundation of vast stretches of land. There is need for checking erosion of hill slopes which contribute significantly to the large quantity of silt in the rivers. The problem of soil conservation in the catchment areas is enormous but so far very little has been done to deal with it.

SALIENT FEATURES OF THE SON BASIN

(i)	Source	At Sonbhadra in the Maikala range in Madhya Pradesh (Latitude 22°44′N, Longitude 82°4′E).		
(ii)	Length	Madhya Pradesh	500 km.	311 miles
		Uttar Pradesh	82 km.	51 miles
		Bihar	202 km.	125 miles
		Total:	784 km.	487 miles
(iii)	Drainage area	Madhya Pradesh	47,656 sq. km.	18,400 sq. miles
		Uttar Pradesh	5,952 sq. km.	2,298 sq. miles
		Bihar	17,651 sq. km.	6,815 sq. miles
		Total:	71,259 sq. km.	27,513 sq. miles
(iv)	Population (1971 census)		7.88 millions	
(v)	Density of Population		111 per sq. km	287 per sq. mile
(vi)	Maximum discharge		N.A.	
(vii)	Minimum discharge at Dehri		21 cumecs	740 cusecs
(viii)	Average annual runoff of the basin		42,308 m.cu.m.	34.3 MAF.
			Thousand hectares	Thousand acres
(ix)	Culturable area (1967-68)		3,598	8,891
(x)	Net area sown (1967-68)		2,174	5,372
(xi)	Gross area sown (1967-68)		2,628	6,494
(xii)	Net area irrigated (1967-68)		336	830
(xiii)	Gross area irrigated (1967-68)		411	1,016
(xiv)	Ultimate irrigation by major & medium projects under operation and construction in 1968-69		596	1,473
			m.cu.m.	MAF
(xv)	Water utilisation, including reservoir losses on completion and full development by major, medium and minor projects under operation and construction in 1968-69	Surface Water	10,335	8.38
		Ground Water	838	0.68
		Total:	11,173	9.06

CHAPTER VI

SON BASIN

The Basin

The Son basin extends over an area of 71,259 sq. km. Lying to the south of the Vindhya range, the basin covers large areas in the States of Madhya Pradesh, Bihar and Uttar Pradesh. The State-wise distribution of the drainage basin is given below:

Madhya Pradesh	47,656 sq. km.
Uttar Pradesh	5,952 „
Bihar	17,651 „
Total	71,259 sq. km.

6.2 The basin is bounded on the north by the Vindhya range and the ridge separating it from the Karamnasa sub-basin, on the east by the Punpun sub-basin and the Chhotanagpur Plateau, on the south by the Baghelkand Plateau and on the west by the Maikala and Bhanrer ranges. The basin is roughly rectangular in shape and has a maximum length of 460 km. in the east-west direction and a maximum width of 220 km. in the north-south direction.

THE RIVER SYSTEM

6.3 The Son, a principal right bank tributary of the Ganga, rises at Sonbhadra in the Maikala range of hills in Madhya Pradesh at an elevation of 600 m. at north latitude 22°44′ and east longitude 82°4′. The river in the initial reach flows in cascades and through a maze of hills and valleys of the Vindhya range. Flowing in a northerly course for about 230 km. it receives from the left its first important tributary namely the Mahanadi at Sarai. Then it meets the scarps of the Kaimur hills and flows in a north-easterly direction before leaving Madhya Pradesh about 8 km. from Deoria village.

Entering the Mirzapur district of Uttar Pradesh, the river flows in an easterly direction and receives its two important tributaries, the Rihand and the Kanhar on its right bank and a third tributary the Ghagar on its left bank.

After leaving Mirzapur district, the Son enters Palamau district in Bihar. Its course in the district lies along a valley 12 to 13 km. in width. During the dry season, the river is shallow and varies in width from 50 to 90 metres meandering from side to side and is easily fordable. The North Koel which is another important tributary joins the Son on its right bank. The river then takes a north-easterly course and enters Shahabad district opposite Akbarpur.

Forming the boundary between the Patna and Shahabad districts, it finally flows through Patna district and joins the Ganga about 16 km. upstream of Dinapur in Patna district. The river has a total length of 784 km. from its source at Sonbhadra to its confluence with the Ganga, of which 500 km. are in Madhya Pradesh, 82 km. in Uttar Pradesh and the balance of 202 km. in Bihar.

A weir across the Son has been constructed at Dehri during 1869–79 providing irrigation facilities to an area of about 0.35 million hectares in the Gaya, Patna and Shahabad districts. Below this weir the river is crossed by a 3,064 m. long railway bridge, said to be the longest in India.

Important tributaries of the Son are the Mahanadi, the Banas, the Gopat, the Rihand, the Kanhar and the North Koel.

6.4 *The Mahanadi* rises in the Mandla district of Madhya Pradesh at an elevation of 600 m. at north latitude 23°7′ and east longitude 80°38′ and traverses the Mandla, Jabalpur and Shahdol districts before joining the Son at Sarai: The river has a total length of 193 km. and has a catchment area of 4,843 sq. km.

6.5 *The Banas* rises on the eastern face of the Vindhya mountains at an elevation of 600 m. at north latitude 23°32′ and east longitude 81°59′ and flows for a distance of about 160 km. It drains an area of 3,507 sq. km. before joining the Son near Demba in the Sidhi district of Madhya Pradesh.

6.6 *The Gopat* rises in the Surguja district of Madhya Pradesh at an elevation of 900 m. at north latitude 23°32′ and east longitude 82°32′ and runs for a total length of 209 km. It drains an area of 5,998 sq. km. before joining the Son near Burdi.

6.7 *The Rihand* river draining an area of about 17,110 sq. km. is the largest tributary of the Son. It rises in the Surguja district of Madhya

Pradesh at an elevation of 900 m. at north latitude 22°38′ and east longitude 83°1′ and flows in a northerly direction through Madhya Pradesh and Uttar Pradesh and joins the Son near Chopan, about 100 km. south of Mirzapur town. The river has a total length of 224 km. The river course is mostly in gorges with alternate pools and rapids and is ideally suited for the generation of hydro-power. The Rihand dam completed in 1966 is situated across this river about 47 km. upstream of its confluence with the Son and the power station has an installed capacity of 300 MW.

6.8 *The Kanhar* river rises in the Surguja district of Madhya Pradesh at an elevation of 900 m. at north latitude 23°3′ and east longitude 83°55′ and after running for a short distance parallel to the North Koel, takes a north-easterly turn. It forms the boundary between the Palamau district of Bihar and the Surguja district of Madhya Pradesh. After flowing for a distance of 80 km., it joins the Son in the Mirzapur district slightly downstream of the confluence of the Rihand. The river has a total length of 214 km. and drains an area of about 5,903 sq. km.

6.9 *The North Koel,* draining an area of about 10,360 sq. km. and having a length of about 212 km., is one of the important tributaries of the Son in Bihar. It rises in the Ranchi district of Bihar at an elevation of 900 m. at north latitude 23°4′ and east longitude 84°28′ and after draining areas in Ranchi and Palamau districts it joins the Son a few kilometres northwest of Hydernagar.

CLIMATE

6.10 The Son basin experiences in summer a maximum temperature of about 43°C in the upper catchment and nearly 49°C in the Plains. The winter temperature in the upper catchment rarely goes below 2°C.

6.11 Rainfall varies from 1,620 mm. in Vindhyan plateau to about 990 mm. in the plains where the Son joins the Ganga. The average annual and monsoon rainfalls in various districts lying in the basin are given in Table 6.1.

6.12 There are 37 rain-gauge stations in the Son basin giving a dispersion of one rain-gauge for every 1,926 sq. km. The distribution of the stations is not even and their number is also not sufficient. It is suggested that a few more rain-gauges to obtain a balanced distribution over the entire basin should be established.

There is no departmental or agro-meteorological observatory of the India Meteorological Department within the basin.

Table 6.1

Rainfall in the Son Basin

(mm)

Name of District	Average annual rainfall	Monsoon rainfall
1	2	3
Madhya Pradesh		
Bilaspur	1,392	1,219
Shahdol	1,397	1,184
Mandla	1,570	1,363
Surguja	1,493	1,300
Sidhi	1,248	1,102
Jabalpur	1,274	1,131
Raigarh	1,620	1,413
Satna	1,100	967
Bihar		
Palamau	1,335	1,140
Gaya	1,151	1,002
Shahabad	1,123	984
Patna	992	963
Ranchi	1,483	1,209
Uttar Pradesh		
Mirzapur	1,134	998

Source: IMD—Monthly and Annual Normals of Rainfall and of Rainy days (1901-1950).

SOILS

6.13 The soils of the districts of Madhya Pradesh lying in the Son basin can be broadly classified as red and yellow soils in the Mandla, Bilaspur, Shahdol, Surguja and Raigarh districts, medium black soil in the Jabalpur and Sidhi districts and mixed red and black soil in the Satna district.*

Mirzapur, which forms part of Vindhyan plateau, is the only district in Uttar Pradesh falling in the Son catchment. The soils of the Vindhyan plateau can be classified as those of the Vindhyan upland, the Vindhyan flats and the Vindhyan lowland. The soils in the Vindhyan uplands are basically alluvial in nature being formed under excessive drainage. The soils are coarse grained, red and very shallow, and poor in nutrients. The soils in the Vindhyan flats have developed under less well drained conditions. The soils contain more fine grained material with better moisture retentivity. The staple crop of these tracts is paddy. The soil of the Vindhyan lowland is alluvial.

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*Soils of India by S. P. Raychaudhari, R. R. Aggarwal, N. R. Datta Biswas, S. P. Gupta and P. K. Thomas.

Ranchi and Palamau districts in Bihar in the basin are hilly in character and consist of red soils. The remaining three districts namely, Gaya, Shahabad and Patna which also fall in the Son basin have essentially alluvial soils belonging to the Gangetic plain. The southern parts of the Shahabad and Gaya districts have forest soils.

LAND USE AND AGRICULTURAL PRACTICES

6.14 Land use details of the Son basin for the year 1967–68 are given below:

Table 6.2

Land Use Details—Son Basin

(Thousand hectares)

Item	State			Total
	Madhya Pradesh	Uttar Pradesh	Bihar	
1	2	3	4	5
Geographical area	4,766	595	1,765	7,126
Reporting area	4,711	595	1,760	7,066
Area under forests	2,034	228	602	2,864
Area not available for cultivation	339	81	124	604
Culturable area	2,278	286	1,034	3,598
Unclutivated culturable area	896	96	432	1,424
Net area sown	1,382	190	602	2,174
Area sown more than once	20	51	203	454
Total cropped area	1,582	241	805	2,628
Net irrigated area	17	47	272	336
Gross irrigated area	17	50	344	411
Percentage of net area sown to culturable area	60.7	66.4	58.2	60.4
Percentage of net irrigated area to culturable area	0.7	16.5	26.3	9.3
Percentage of net irrigated area to net sown area.	1.2	24.8	45.1	15.4

Except in the lowermost reaches when the river emerges into the Gangetic plain in the Shahabad district, the river flows in hilly and well forested areas. Nearly 40.5% of the total drainage area of the Son basin is under forests. Out of a total reporting area of 7.07 million hectares, only 50.9% is culturable and of the culturable area, only 60.4% is cultivated annually.

6.15 Irrigation in an organised way was first introduced in the Son basin with the commissioning of the Son Canals in 1879. In Bihar nearly 45.1% of the area cultivated in the basin has irrigation facilities, mostly under the Son Canals. In contrast to this, Madhya Pradesh has practically no development of irrigation of any sort in the basin and barely 1.2% of the area cultivated receives irrigation. Taking the basin as a whole, 15.4% of the cultivated area has irrigation facilities.

6.16 Agriculture in the Son basin, whether under irrigated or unirrigated conditions is dominated by food crops. Paddy is the most important irrigated crop in the basin. In Madhya Pradesh it constitutes nearly 51.8% of the area irrigated whereas in Bihar it is grown over 71.2% of the irrigated area. In Uttar Pradesh also paddy is grown over nearly 79% of the area irrigated. Details of the irrigated crops during 1967–68 are given below:

Table 6.3

Irrigated Crops—Son Basin

(thousand hectares)

Name of crop	State						Total for the basin	
	Madhya Pradesh		Uttar Pradesh		Bihar			
	Area	%age to total	Area	%age to total	Area	%age to total	Area	%age to total
1	2	3	4	5	6	7	8	9
Rice	8.8	51.8	39.1	79.0	245.0	71.2	292.9	71.4
Wheat	2.0	11.7	3.1	6.3	72.0	20·0	77.1	18.8
Barley	0.3	1.8	2.6	5.3	3·9	1.1	6.8	1.7
Gram	0.2	1.2	1.1	2.2	4.0	1.2	5.3	1.3
Sugarcane	0.7	4.1	1.3	2.6	5.3	1.5	7.3	1.8
Other food crops	4.5	26.5	2.3	4.6	12.9	3.8	19.7	4.8
Total food crops	16.5	97.1	49.5	100.0	343.1	99.7	409.1	99.7
Non-food crops	0.5	2.9	Neg.	—	0.9	0.3	1.4	
All crops	17.0	100.0	49.5	100.0	344.0	100.0	410.5	100.0

Crop Seasons

6.17 There are two main crop seasons in the basin, namely the kharif and rabi. The kharif season begins with the onset of the southwest monsoon in June and extends up to October. The rabi season lasts from November to March-April.

REGIONAL ECONOMY

Population

6.18 On the basis of the 1971 Census* and the percentage of the area of each district within the basin to the district as a whole, total population in the basin is about 7.88 millions. The State-wise distribution is:

Madhya Pradesh	3.66 millions
Bihar	3.41 „
Uttar Pradesh	0.81 „
Total	7.88 millions

The average density of poplation in the basin is 111 persons per sq. km. against 182 for India as a whole. As can be expected the districts in the Gangetic plain namely, Gaya, Patna and Shahabad have comparatively higher densities. Patna has the highest density with 635 persons per sq. km. and Gaya comes next with 361 persons per sq. km. The Surguja district in Madhya Pradesh has the lowest density with 59 persons per sq. km.

6.19 There are no cities within the basin having a population of one lakh people or more. Except in the Patna district of Bihar and the Jabalpur district of Madhya Pradesh more than 88.2% people live in villages. Urbanisation in Jabalpur is highest with 40.5% people in the district living in towns and cities. In Patna 22.5% of the people live in urban areas. The main occupation of the people is agriculture. Slightly more than 33.3% of the total population is the working force of which nearly 50.9% are cultivators and 26.5% work as agriculture labourers. The remaining 22.6% of the working force are employed in other services.

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*Census Paper I of 1971 (Supplementary), Registrar-General (India).

Forests and Agriculture

6.20 The Son basin is well forested. Nearly 40.5% of the total geographical area is under forests. The culturable area constitutes slightly more than 50.9% of the total area of the basin. Out of a total culturable area of 3.6 million hectares, only about 60.4% of the area is cultivated annually. The main feature of agriculture in the basin is that practically the entire area is under food crops. In Bihar nearly 45.1 per cent of the area cultivated annually has irrigation facilities while hardly 1.2 per cent of the cultivated area in Madhya Pradesh is irrigated. This shows the enormous disparity in irrigation development between the regions. In Bihar, extensive irrigation facilities have been developed in the Shahabad and Gaya districts under the Son canals taking off from the anicut across the Son at Dehri (since replaced by a barrage constructed about 8 km. upstream of the old weir).

Power

6.21 According to surveys conducted by the Central Water and Power Commission, the hydro-power potential of the Son basin is 554 MW at a 60 per cent load factor. Against this, the development of hydro-power has also been considerable. The Rihand Hydroelectric project (completed in 1966) and the Obra hydroelectric scheme (scheduled to be completed in 1970–71) have, between them a total installed capacity of 399 MW.

In addition to the above, a thermal station at Obra with an installed capacity of 300 MW has been completed. The 5th unit (50 MW) of this scheme is scheduled to be commissioned in 1970–71. The Uttar Pradesh Government has also proposed the extension of the Obra thermal station. Stage I of the extension programme (scheduled to be completed during IV Plan) will have an installed capacity of 300 MW while under Stage II (to be completed during V Plan), an additional 600 MW would be developed.

*Mineral wealth**

6.22 Coal and limestone are the two important minerals which are found in large quantities in the Son basin.

Coal: It is found in the Shahdol, Surguja and Sidhi districts of Madhya Pradesh and Palamau district of Bihar.

Limestone: It is found in the basin mainly in Shahabad district in Bihar.

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*Techno-Economic Surveys of Bihar, Madhya Pradesh and Uttar Pradesh, NCAER.

Other districts which have got small deposits are Jabalpur, Surguja, Raigarh and Bilaspur in Madhya Pradesh and Ranchi and Palamau in Bihar.

Bauxite: It is found in the Surguja, Bilaspur, Raigarh and Jabalpur districts of Madhya Pradesh and Ranchi district in Bihar.

Iron ore: Deposits are found in the Jabalpur district of Madhya Pradesh. These are small.

Manganese: Deposits are found in the Bilaspur and Jabalpur districts of Madhya Pradesh and these are also very limited in extent.

Fire clay and *China clay*: Deposits are found in the Jabalpur, Bilaspur, Satna and Shahdol districts of Madhya Pradesh and Palamau district of Bihar.

Corondum: It is found in the Sidhi district of Madhya Pradesh.

Mica is found in the eastern part of the Gaya district in Bihar.

Industries

6.23 Except for the cement factory near Dalmia Nagar and some small metallurgical, chemical and other light industries in towns like Katni, there are very few big industries in the basin. As agriculture is the most important occupation of the people, some industries based on agricultural produce, like cotton and sugar mills are also found in some parts of the basin.

Communications

6.24 As much of the drainage area of the Son basin is in the hills and forests, the basin does not have a good communication system except in the plains of the Shahabad, Patna and Gaya districts. All important towns are connected by means of State highways and railways.

Except in its lower reaches, the Son is not navigable.

WATER RESOURCES

Surface Water

6.25 The surface water potential of the basin has been assessed at different times by different authorities. The first assessment was made by the first Indian Irrigation Commission. As there were no records to show the surplus passing to the sea, reliance was placed upon a coefficient of runoff, selected with regard to the rainfall and other conditions, and to the coefficient of actual flow, determined for other catchments. The Commission, however, cautioned that the estimates arrived at by the method must be regarded as mere rough approximations. According to the above assessment, the total annual surface flow of the Ganga below Varanasi was estimated at 325,646 m. cu. m.*

6.26 In 1949 when the assessment of the basin-wise water resources of the country was made on the basis of Khosla's formula, the annual runoff of the Son basin was estimated at 42,888 m. cu. m.**

6.27 According to the studies carried out by the Central Water and Power Commission, the average annual yield of the Son basin on the basis of Strange's formula is 42,308 m. cu. m.***

6.28 One other estimate places the average annual yield of the Son basin as 30,000 m. cu. m.

6.29 The average annual runoff of the Son at Dehri anicut, as assessed by the State Government with the available flow data at the anicut is 48,106 m. cu. m. Adding to this, the likely runoff from the catchment below the anicut up to its confluence with the Ganga, the total runoff for the entire basin as assessed by the State Government is 49,339 m. cu. m.

6.30 The Son river has been gauged at the Dehri anicut for a considerable length of time. Daily gauge and discharge data at this site is available for the last 45 years. A number of gauge discharge sites on the Son and its tributaries have been established since 1958.

Ground Water

6.31 The topography of the Son basin is such that most of the drainage area in the Madhya Pradesh and Uttar Pradesh is hilly and the economic development of ground water in this region appears to be remote. It is only in the districts of Gaya, Shahabad and Patna in Bihar that the development of ground water is possible. The Geological Survey of India has carried out studies practically in the entire alluvial area of the Gaya and Shahabad districts between the Ganga in the north and hard rock areas in the south. Ground water occurs under water table conditions. Depth of water ranges from 2 to 8 m. in winter and 4 to 12 m. in summer. In the south Shahabad, the depth to the water table ranges from 2 to 10 m. in winter and 5 to 15 m. in summer. In the north Shahabad Koelwar-Buxar area where intensive ground water irrigation through tubewells is going on at present, the depth to water is 2 to 8 m. The alluvium increases in thickness from about 10 m. in the south to nearly 700 m. towards the Ganga and the percentage of granular zone increases correspondingly.

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*Report of the Indian Irrigation Commission (1901-03).

**An appraisal of water resources by Dr. A. N. Khosla, UNESCO.

***Report of the technological possibilities of irrigation projects in India, Central Water and Power Commission (Unpublished).

Ground water development in the Son will have to be only in the plains districts of Bihar. The quantity of groundwater available has not been assessed so far. It appears, however, that the development of ground water resources on a large-scale is possoible in the plains districts judging from the intensive tubewell irrigation being done at present

EXISTING DEVELOPMENT

6.32 Organised irrigation development in the Son basin started with the Son Canal ex-Dehri Anicut. The idea of using the water of the Son for irrigation was first thought of around 1850 by Col. C. H. Dickens and for many years the subject was under discussion. The project was undertaken by the East India Irrigation and Canal Company but was handed back to the Government in 1868 and the work was not actually started till the following year. The project was ultimately completed in the year 1879. The project consists of an anicut across the river Son at Dehri. The length of the anicut is nearly 4 km. and two short canals namely the Western and Eastern Main Canals 20 km. and 11 km. in length respectively take off on either side of the anicut. Two navigation canals, the Buxar and the Arrah Canals take off from the Western Main Canal while the Patna Canal takes off from the Eastern Canal. The Western and the Eastern Canals with a full supply capacity of 130.3 cumecs and 73.6 cumecs respectively command an area of nearly 0.6 million hectares. The annual irrigation is of the order of 0.35 million hectares.

6.33 Another irrigation system making use of the water of the Son basin is the Ghagar Canal Project. The scheme consists of a dam across the river Ghagar a tributary of the Son and a diversion canal taking the water into the Tons sub-basin to irrigate lands in the Mirzapur district in Uttar Pradesh (details of the scheme are given under the paragraphs 6.35 and 6.46).

6.34 To meet the increasing demand for water in the command area of the Son Canal and to improve the existing irrigation system, the Bihar State Government undertook, during the Second Plan period, the construction of a barrage across the Son about 8 km. upstream of the anicut at Dehri. The existing canals are connected to the barrage by means of link canals. The scheme also includes remodelling of the Son canals. In addition to stabilising irrigation in the old command, irrigation of 0.124

million hectares is provided for. The work on the project is expected to be completed by the end of the Fourth Five Year Plan. The cost of the project is estimated to be Rs. 183.2 million.

6.35 The Bihar Government has also proposed the construction of high level canals, ex-Son Barrage for making use of the regulated releases from the Rihand Dam in Uttar Pradesh. The scheme as proposed by the State envisages the construction of the Eastern and Western High Level Canals taking off at 8 km. of the link canals on the right and the left flanks of the Son Barrage. The additional area expected to be brought under irrigation under this scheme is 0.102 million hectares. The project started in 1968 is expected to be completed during the Fourth Five Year Plan. The estimated cost is Rs. 88.4 million.

The success of the Son High Level Canal depends on the assured regulated releases from the Rihand Dam. Negotiations between the Governments of Uttar Pradesh and the Bihar regarding the minimum flow expected from the Rihand Dam have not so far been successful. The Bihar Government has proposed the North Koel Project as an alternate scheme. This project includes the construction of a dam across the North Koel—a tributary of Son joining it upstream of the barrage, to supply water to the Son High Level Canals. The project would also provide irrigation to 0.178 million hectares under its own command.

6.36 Besides the above major projects, many medium projects have also been undertaken by the concerned State Governments in the basin. Salient features of the major and medium projects under operation and construction in the basin are given below:

Table 6.4

Projects Completed and Under Construction in the Son Basin

Name of project	Location (District)	Date of completion	Estimated cost (Rs. million)	Ultimate irrigation (hectares)
1	2	3	4	5
Madhya Pradesh				
(a) Completed Projects				
(i) Pre-Plan Projects		NIL		
(ii) Plan Projects		NIL		

Table 6.4—Contd.

1	2	3	4	5
(b) Continuing Projects				
Jhirgiri	Jabalpur	V Plan (Probable)	7.49	1,943
Total for Madhya Pradesh			7.49	1,943
*Uttar Pradesh**				
(a) Completed Projects				
(i) Pre-Plan Projects				
Ghagar Canals		Benefits in Tons sub-basin.		
(ii) Plan Projects		NIL		
(b) Continuing		NIL		
Bihar				
(a) Completed Projects				
(i) Pre-Plan Projects				
Son Canals	Shahabad and Gaya	1879	26.82	347,230
(ii) Plan Projects				
Adri	Gaya	1959	1.53	4,250
Jinjoi	Palamau	1963	1.48	3,040
Chako	Palamau	1962-63	1.59	2,330
(b) Continuing Projects				
Son Barrage Project	Shahabad	IV Plan (Probable)	183.20	124,000
Son High Level Canals	Shahabad & Gaya	,,	88.40	101,980
Banki Lift Canal	Palamau	V Plan (Probable)	7.80	5,868
Araj	Palamau	V Plan (Probable)	4.12	5,403
Total (Bihar)			414.94	594,101
Grand Total (Basin)			422.43	596,044

Source: (i) CW&PC. Note Volumes on irrigation chapter of Madhya Pradesh (March, 1970), Uttar Pradesh (March, 1970) and Bihar (March, 1969).
(ii) Irrigation Statistics of India (1960-61)—CW&PC.

*'Rihand Dam' in Uttar Pradesh has not been included in the table as it is a Power Project.

Son Canal System including the Son High Level Canals constitutes nearly 96% of the total area expected to be brought under irrigation from all the projects under operation and construction in the basin.

6.37 Extent of area under irrigation from tanks, wells and other sources is also considerable. The sourcewise irrigation in the basin during the year 1967–68 is given below:

Table 6.5

Source-wise Irrigation—Son Basin

(Thousand hectares)

Source of irrigation	Area irrigated			Total	Percentage to total area irrigated
	Madhya Pradesh	Uttar Pradesh	Bihar		
1	2	3	4	5	6
Canals	8.7	27.2	118.0	153.9	45.9
Tanks	1.2	2.0	18.0	21.2	6.3
Wells (including tubewells)	5·4	6.7	46.1	58.2	17.3
Other sources	1.6	11.2	89.4	102.2	30.5
Total	16.9	47.1	271.5	335.5	100.0

Irrigation under canals and other sources forms the bulk of the total irrigated area. These two sources between them account for nearly 76.4% of the total area irrigated.

6.38 The average delta obtained under the Son Canals, which is the most important system in the basin, is 1.22 m. On this basis, the total water diverted for irrigating 0.596 million hectares, which is expected to be irrigated when all the major and medium projects so far undertaken in the basin are completed and fully developed, would be of the order of 7,278 m. cu. m.

6.39 Data regarding the delta obtained under minor schemes is not available. Therefore, the same delta as obtained under the Son Canals has been assumed for working out the water utilisation under the minor schemes. The total area irrigated during 1968–69 under minor schemes was 0.21 million hectares. The water diverted under minor schemes would be of the order of 2,617 m. cu. m.

Reservoir Losses

6.40 On the basis of assumptions detailed in para 1.33 the reservoir losses from the various schemes in the basin will be as under:

(i) Major and Medium Schemes	57 m. cu. m.
(ii) Minor Schemes (tank)	234 m. cu. m.
Total	291 m. cu. m.

6.41 Thus, the annual utilisation, including reservoir losses, from all major, medium and minor schemes under operation and construction in the basin would be of the order of 10,186 m. cu. m. (9,348 m. cu. m. of surface + 838 m. cu. m. of ground). Adding to this, about 370 m. cu. m. diverted to Tons sub-basin (under the Ghagar Canal) and 617 m. cu. m. of reservoir losses in Rihand Dam, total water utilised so far in Son basin would be 11,173 m. cu. m.

Water used for industries at present is negligible. However, this aspect should not be lost sight of in planning future developments.

FUTURE DEVELOPMENT

6.42 As stated in para 8.58, utilisation of surface water in the Son basin from all the projects in hand or already constructed is of the order of 10,335 m. cu. m. The average runoff of the basin according to the studies of the Central Water and Power Commission is 42,308 m. cu. m., which leaves a large balance of surface water in addition to ground water for future development.

There are two major projects to be taken up in the basin, namely the Demba Project in Madhya Pradesh and the Kutku Project in Bihar. Eight medium and a number of minor schemes are also proposed to be taken up in the basin in the future.

Demba Project

6.43 The Demba Project (Bansagar Project as it is now called by the State) consists of a dam across the Son in Shahdol district to irrigate about 0.06 million hectares in the Sidhi and Shahdol districts. The project also envisages the transvalley diversion of waters to irrigate an additional

0.188 million hectares in the Rewa and Satna districts and to generate 253 MW of power.

Kutku Project

6.44 The Kutku Project in Bihar provides for the construction of a masonry dam across the North Koel river, a tributary of the Son, and a pick-up weir lower-down at Mohammadganj. The project will supplement the water required for the Son High Level Canals and also provide irrigation to 0.178 million hectares under its own command.

6.45 The medium projects to be taken up in the future in the basin are:

(1) Bhonpur Dam
(2) Gajanli Dam
(3) Banas Dam
(4) Bagdhra Dam
(5) Surajpur Dam
(6) Amkuni Dam
(7) Surma Dam
(8) Barodivi Dam

The above medium projects are expected to provide irrigation to about 0.39 million hectares.

6.46 The major and medium projects to be taken up in the basin in future will provide irrigation to a total area of 0.82 million hectares. Assuming a delta of 1.22 m. as is obtained under the Son Canals, the total water diverted for irrigating 0.82 million hectares will be 9,868 m. cu. m. Taking the reservoir losses at 20 per cent of the water diverted by the various projects, the water utilisation, including reservoir losses, from the major and medium schemes to be taken up in the basin in future will be of the order of 11,842 m. cu. m.

FLOODS, WATERLOGGING AND DRAINAGE

6.47 The Son river flows for the greater part of its length in hilly areas and is contained within well defined banks. There is no flood problem in this reach. It is only in the lower reaches, when the river comes out into the plains, that there is a certain amount of spilling over of its banks and the flooding of the adjoining territories. The flood problem in the basin is experienced in the low-lying plains between Arrah and Maner.

The most serious floods occurred in 1848, 1869, 1884, 1888, 1901, and 1923. During recent times, there were floods of a minor order in 1953, 1956 and 1957. The main characteristic of floods in the basin is that they are of short duration hardly lasting for 4 days. They also recede very rapidly.

6.48 There are no reports of waterlogging or drainage problems in the Son Canal System.

SOIL CONSERVATION

6.49 Soil erosion in Madhya Pradesh is most critical where overgrazing of livestock is permitted on the hill pasture and in the pastured wood lands. Some accelerated erosion is observed where cultivation has been extended up to the hill slopes. In Uttar Pradesh, the land along the natural drainages has been severely damaged by gully erosion and ravine formation. The plains, on account of the shallower soil and the steeper slope, are also subject to severe erosion. The land surfaces of Chhotanagpur, being uneven, are also subject to erosion. Slopes of these lands, are variable, a slope of 5 per cent or more being not uncommon, though the average slope may be 2 per cent. On the medium land, where unterraced cultivation has continued for some time, the formation of gullies in the drainage way is common. The gullies are V-shaped and sometimes the banks collapse and pose a serious menace to cultivated land.

6.50 No project in the basin has been included under the centrally sponsored programme of soil conservation in catchments of major river valley projects.

6.51 Data on silting of reservoirs and tanks in the basin is not available. To conserve the storage capacities of existing and proposed reservoirs, soil conservation measures are necessary and have to be undertaken.

SALIENT FEATURES OF THE BASIN OF THE GANDAK AND OTHER LEFT BANK TRIBUTARIES UP TO INTERNATIONAL BORDER

(i) Source:	The Gandak	North-east of Dhaulagiri in Tibet (Latitude 29°18′N, Longitude 83°58′E).
	The Burhi Gandak	Springs of the Someshwar hills in the Champaran district (Latitude 27°22′N, Longitude 84°8′E).
	The Bagmati	In the Shivpuri range of hills in Nepal (Latitude 27°47′N, Longitude 85°17′E).
	The Kosi	In the Himalayan region in Tibet (Latitude 27°58′N, Longitude 87°51′E).
	The Kamla	In the Mahabharat range of hills in Nepal (Latitude 27°15′N, Longitude 85°57′E).
	The Mahananda	In the Mahaldiran hills in the Darjeeling district. (Latitude 26°58′N, Longitude 88°9′E).

		Km.	Miles
(ii) Length:	The Gandak	630	391
	The Burhi Gandak	320	199
	The Bagmati	396	246
	The Kamla	328	204
	The Kosi	468	291
	The Mahananda	376	234

(iii) Drainage area in India:	Bihar	47,535 sq. km.	18,353 sq. miles
	West Bengal	8,795 sq. km.	3,395 sq. miles
	Uttar Pradesh	968 sq. km.	374 sq. miles
	Total	57,298 sq. km.	22,122 sq. miles
(iv) Population (1971 Census)		26.22 millions	
(v) Density of population		457 per sq. km.	1,184 per sq. mile
(vi) Average annual runoff of the basin		134,277 m. cu. m.	108.86 MAF

		Thousand hectares	Thousand acres
(vii) Culturable area (1967-68)		4,378	10,818
(viii) Net area sown (1967-68)		3,851	9,516
(ix) Gross area sown (1967-68)		5,207	12,867
(x) Net area irrigated (1967-68)		374	924
(xi) Gross area irrigated (1967-68)		475	1,174
(xii) Ultimate irrigation by major and medium projects under operation and construction in 1968-69		2,674	6,608
		m. cu. m.	MAF
(xiii) Water utilisation, including reservoir losses on completion & full development from major, medium and minor projects under operation and construction in 1968-69	Surface water	26,006	21.08
	Ground water	1,068	0.87
	Total	27,074	21.95

CHAPTER VII

BASIN OF THE GANDAK AND OTHER LEFT BANK TRIBUTARIES UP TO INTERNATIONAL BORDER

The Basin

The basin, in Indian territory, extends over an area of 57,298 sq. km., and lies between east longitudes 83°48′ to 88°42′ and north latitudes 24°28′ to 27°32′. Lying to the north of the Ganga, the basin crops practically the whole of North Bihar, portions of the Darjeeling, West Dinajpur and Malda districts of West Bengal and small portions of the Deoria and Gorakhpur districts of Uttar Pradesh. The state-wise distribution of the drainage area in India is given below:

Bihar	47,535 sq. km.
West Bengal	8,795 sq. km.
Uttar Pradesh	968 sq. km.
Total	57,298 sq. km.

7.2 The basin is bounded on the north by the Himalayas, on the east by the ridge separating it from the Brahmaputra basin, on the south by the Ganga and on the west by the ridge separating it from the Ghaghara sub-basin. The basin has the shape of a rectangle, with the foot hills of the Himalaya and the Ganga forming parallel sides of the rectangle. It has a maximum length of 370 km. in the east-west direction and a maximum width of 250 km. in the north-south direction.

THE RIVER SYSTEM

7.3 The more important rivers in the basin are the Gandak, the Burhi Gandak, the Bagmati, the Kamla, the Kosi and the Mahananda. All these rivers rise in the Himalayan ranges in Nepal or beyond. The approximate drainage areas in India of the various rivers flowing through the basin are given below:

	Name of the River	*Drainage area in India*
1.	Gandak	7,420 sq. km.
2.	Baya	2,250 sq. km.
3.	Burhi Gandak	10,150 sq. km.
4.	Odhwara Group of rivers	
	(i) Bagmati	6,320 sq. km.
	(ii) Kamla	2,980 sq. km.
5.	Kosi	11,070 sq. km.
6.	Minor basins between the Kosi and the Mahananda	5,580 sq. km.
7.	Mahananda	11,530 sq. km.
	Total	57,300 sq. km.

The more important rivers in the basin are described in the following paragraphs:

7.4 *The Gandak,* known as the Kali or Krishna Gandak in the upper reaches rises at an altitude of 7,620 m. in Tibet near the Nepal border to the north-east of Dhaulagiri at north latitude 29°18′ and east longitude 83°58′. After flowing for about 100 km. in a south-south-easterly direction in Nepal and receiving a number of tributaries, like the Mayangadi, the Bari and the Trisuli, the Gandak debouches into the plains of the Champaran district of Bihar at Tribeni. At this point two more tributaries namely the Panchnad and the Sonhad join the river. The Gandak Project which is expected to provide irrigation to about 1.47 million hectares in Bihar, Uttar Pradesh and Nepal is under construction at Tribeni. Thereafter the river flows in a southerly direction and forms the boundary between Uttar Pradesh and Bihar. Before joining the Ganga near Patna, the river flows through Champaran, Saran and Muzaffarpur districts. It runs a course of about 380 km. in Nepal and Tibet and about 250 km. in India and drains a total area of about 46,300 sq. km. of which 7,620 sq. km. lie within India.

7.5 *The Burhi Gandak* known as the Sikarna in its upper reaches rises in Champaran district from the springs of the Someshwar hills at an elevation of 300 m. at north latitude 27°29′ and east longitude 84°8′. The river is practically a collection of hill torrents rising from springs. After flowing for a distance of about 56 km. the river takes a southerly turn where it is joined by the Dubhara and the Teur. From this point the river takes a south-easterly direction and flows through the Muzaffarpur district for about 32 km. In this reach the river has a tendency to spill over its banks and a number of spill channels take off and rejoin it later. The Burhi Gandak after flowing through Darbhanga and Monghyr districts joins the Ganga opposite the town of Monghyr. The river drains a total area of 10,150 sq. km. and has a length of about 320 km.

The rivers draining the area to the east of the Burhi Gandak and up to the Kosi are known as the Adhwara group of rivers. The most important of these are the Bagmati and the Kamla. The chief characteristics of these rivers are their steep gradients in the Himalayan region and their flatter slopes lower down. This results in the silt load being dropped in the middle reaches and the consequent spill over of water resulting in the transfer of flood waters from one river to another. These rivers have a marked tendency to shift their course due to the topography of the terrain. In recent times the Kamla and the Bagmati have abandoned courses and have opened out new channels causing extensive flooding.

7.6 *The Bagmati* rises in the Shivpuri range of hills in Nepal at an elevation of 1,500 m. at north latitude 27°47′ and east longitude 85°17′. The river flows in a westward direction draining the Kathmandu valley. After draining areas in Nepal, the river cuts across the Mahabharat range of hills and enters India at Rasulpur in Muzaffarpur district. During its course through the district a number of spill channels take off from the Bagmati to rejoin it later. The river ultimately joins the Kosi near Barna village, on the border of Darbhanga and Saharsa districts, after draining a total area of about 13,400 sq. km., of which 6,320 sq. km. lie in India.

7.7 *The Kamla* rises in the Mahabharat range of hills in Nepal at an elevation of 1,200 m. at north latitude 27°15′ and east longitude 85°57′. During its course in Nepal, the Kamla receives a number of tributaries like the Chandaha, the Thakur and the Jawakhola. After passing through a gorge above Chanphat it debouches into the terai area of Nepal at Chispani. After flowing for about 50 km. in Nepal, the river enters Indian territory near Jayanagar in Darbhanga district. Later it follows the course of the Dhavri Nadi and the Soni for a short distance and finally adopts the course of the Balan. The river, thereafter known as Kamla-Balan, flows in a south-easterly direction till it joins the Kosi on the border of the Darbhanga and Saharsa districts.

7.8 *The Kosi* is formed by the confluence of three streams namely the Sun Kosi, the Arun Kosi and the Tamur Kosi, all taking their origin in the Himalayan region of Nepal and Tibet. The Arun Kosi is the biggest of the three streams and has two of the highest peaks in the world namely Mount Everest and Mount Kanchanganga in its catchment. After the confluence of the three streams, the Kosi flows in narrow gorge for about 10 km. and debouches into the plains near Chatra. The river enters Indian territory about 25 km. below the Chatra gorge at Hanumannagar where a barrage has been constructed across it. The project provides irrigation to about 1.04 million hectares in Darbhanga, Purnea and Saharsa districts. From the point where it debouches into the plains the Kosi runs in a sandy tract and almost in level plains and finds its way southwards into the Ganga through a number of channels. In each of these channels the bed is gradually raised by silt and sand brought down by the river. When the river is swollen by heavy rains it cuts through the friable banks and opens new channels for itself, forming a fan shaped inland delta in the lowlying country. The apex of the delta is at the point where the river debouches into the plains at Chatra and its sides passing near Purnea on the east and Darbhanga on the west. The Kosi is well-known for its tendency to change its course generally in a westward direction. During the course of the last 200 years, the river has shifted westwards for a distance of about 112 km. and has laid waste large tracts of agricultural land in the Darbhanga and the Purnea districts, by depositing coarse silt. The river drains a total area of about 74,500 sq. km. of which 11,070 sq. km. lie within India.

7.9 *The Mahananda* rises in the Mahaldiran hills of the Himalayas in the Darjeeling district of West Bengal at an elevation of 2,100 m. at north latitude 26°58′ and east longitude 88°9′. The first 20 km. of its course lie in the hills of Darjeeling whereafter it flows in a south-westerly direction forming the boundary between India and Bangladesh till it is joined by the Balsan. Lower down it is joined by the Mechi at Deshitoli. The combined streams of the Ratva and the Kankai originating in Nepal then join the Mahananda. The Kankai is an erratic stream which frequently shifts its course due to the heavy silt load carried by it during floods. The Mahananda then flows in a southwesterly direction for about 64 km. till it is joined by the combined stream of the Nagar and the Kulik and enters West Bengal. It then flows for about 60 km. in the State when it is joined by the combined stream of the Kamla, the Mahananda (a tributary) and the Kalindri at Malda on the right bank, and the Tangan on the left bank. The river then flows south forming the boundary between India and Bangladesh for about 6 km. and enters Bangladesh to join the Ganga at Godagiri. The river drains a total area of about 20,600 sq. km. of which 11,530 sq. km. lie within India.

CLIMATE

7.10 Except in the snow bound areas and the hills of Nepal, the basin experiences very hot summers and severe winters. The summer months of April and May are the hottest with the maximum temperature going up to 44°C. Humidity is lowest during these two months. The winter temperature goes down to nearly 1°C in January. The monsoon months are from June to September and the humidity during these months is generally 80 per cent or more.

7.11 The area receives most of its rainfall during the south-west monsoon from June to September, though rain during May and October is not infrequent. The north-east monsoon lasting from October to December-January, is of a smaller magnitude but benefits the rabi crops. The average annual rainfall and the south-west monsoon rainfall in different districts lying in the basin are given below:

Table 7.1

Rainfall in the Basin

(mm)

Name of State/District	Average annual rainfall	Average monsoon rainfall (June-September)	
1	2	3	
Uttar Pradesh			
Deoria	1,145	988	
Gorakhpur	1,364	1,182	
Bihar			
Saran	1,121	971	
Champaran	1,392	1,193	
Muzaffarpur	1,184	1,009	
Darbhanga	1,250	1,044	
Monghyr	1,206	1,009	
Bhagalpur	1,166	946	
Saharsa	1,385	1,137	
Purnea	1,585	1,293	
West Bengal			
Malda	1,540	1,210	
Darjeeling*	3,092	2,478	*Darjeeling Observatory
West Dinajpur	1,635	1,283	

Source: IMD—Monthly and Annual Normals of Rainfall and of rainy days (1901-50).

7.12 There are 26 rain-gauge stations in the Gandak catchment area of which 18 are in the trans-Himalayan region. This gives an average of one rain-gauge for 1,800 sq. km. The total number of rain-gauge stations in the Kosi catchment is 77 of which 39 are in the trans-Himalayan region and 38 in the rest of the catchment area. This gives an average of one rain-gauge station for about 1,000 sq. km. The distribution of the stations is not even and their number is also not sufficient. It is suggested that a few more rain-gauges to obtain a balanced distribution over the entire basin should be established.

There are no departmental or agro-meteorological observatories of the India Meteorological Department within the basin.

SOILS

7.13 No detailed soil survey of the basin has yet been made. However, the general data regarding the soils of India indicates that mainly alluvial, calcareous alluvial, terai, peaty, saline peaty and red loamy soils occur in the basin. The principal soil types found in the various districts lying in the basin are given below:*

Table 7.2

Soils in the Basin

District	Type of Soil
1	2
Uttar Pradesh	
Deoria	Alluvial and calcareous alluvial
Gorakhpur	Calcareous alluvial and terai
Bihar	
Saran	Alluvial and calcareous alluvial
Champaran	Alluvial, calcareous alluvial and terai
Muzaffarpur	Alluvial and calcareous alluvial
Darbhanga	Alluvial and calcareous alluvial
Monghyr	Alluvial, calcareous alluvial, peaty and saline peaty
Bhagalpur	Alluvial

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*Indian Crop Calendar, Ministry of Food, Agriculture, Community Development and Cooperation (1967).

Table 7.2—Contd.

1	2
Saharsa	Alluvial, calcareous alluvial, peaty and saline peaty
Purnea	Alluvial and terai
West Bengal	
Malda	Alluvial red and yellow
Darjeeling	Terai
West Dinajpur	Alluvial

LAND USE AND AGRICULTURAL PRACTICES

7.14 Land use details in the basin for the year 1967–68 are given below:

Table 7.3

Land Use Details in the Basin

(Thousand hectares)

Item	State			Total
	Uttar Pradesh	Bihar	West Bengal	
1	2	3	4	5
Geographical area	97	4,753	880	5,730
Reporting area	96	4,702	873	5,671
Area under forests	1	124	44	169
Area not available for cultivation	9	1,003	112	1,124
Culturable area	86	3,575	717	4378
Uncultivated culturable area	7	480	40	527
Net area sown	79	3,095	677	3,851
Area sown more than once	28	1,162	166	1,356
Total cropped area	107	4,257	843	5,207
Net irrigated area	31	306	37	374
Gross irrigated area	32	402	41	475
Percentage of net area sown to culturable area	91.9	86.6	94.4	88.0
Percentage of net irrigated area to culturable area	36.2	8.5	5.2	8.6
Percentage of net irrigated area to net sown area	39.4	9.9	5.5	9.7

Nearly 97 per cent of the basin lies in the plains. About 77.2 per cent of the area is culturable and of the culturable area of 4,378 million hectares, an area of 3,851 million hectares i.e., 88 per cent is cultivated annually.

Irrigation facilities in the area so far have been very meagre. Hardly 8.6 per cent of the area cultivated annually has irrigation facilities. This position will, however, improve when the Kosi and the Gandak projects are completed.

7.15 As in other parts of India, agriculture whether under irrigated or unirrigated conditions is dominated by food crops. Practically the entire area under cultivation is under food crops. However, some portion in north Bihar does have areas under non-food crops like poppy and oil seeds. The cropping pattern in Bihar and West Bengal under irrigated conditions is characterised by the predominance of paddy while the portion that lies in Uttar Pradesh grows rabi crops like wheat, barley and pulses. The details of the irrigated crops during 1967–68 are given below:

Table 7.4

Irrigated Crops in the Basin

(Thousand hectares)

Item	State						Total for the basin	
	Uttar Pradesh		Bihar		West Bengal			
	Area	%age	Area	%age	Area	%age	Area	%age
1	2	3	4	5	6	7	8	9
Rice	—	—	253.8	63.2	31.6	77.2	285.4	60.2
Wheat	14.1	44.3	72.7	18.1	2.7	6.5	89.5	18.9
Barley	7.0	22.0	23.4	5.8	0.9	2.2	31.3	6.6
Gram	1.2	3.8	3.5	0.8	—	—	4.7	1.0
Sugarcane	4.1	12.9	2.7	0.7	0.6	1.5	7.4	1.5
Other food crops	5.4	17.0	41.3	10.3	4.8	11.6	51.5	10.8
Total food crops	31.8	100.0	397.4	98.9	40.6	99.0	469.8	99.0
Non-food crops	—	—	4.3	1.1	0.4	1.0	4.7	1.0
All crops	31.8	100.0	401.7	100.0	41.0	100.0	474.5	100.0

Crop Seasons

7.16 The cropping seasons are broadly classified as the kharif and the rabi. The kharif season begins with the onset of the south-west monsoon in June and extends up to October. The rabi season lasts from November to March-April. Under irrigated conditions paddy is grown during the rabi season as a second crop.

REGIONAL ECONOMY

Population

7.17 On the basis of the 1971 Census* and the percentage of the area of each district within the basin to the district as a whole, the total population in the basin is about 26.22 millions. The state-wise distribution is as follows:

Uttar Pradesh	0.50 million	(1.9%)
Bihar	22.46 „	(85.7%)
West Bengal	3.26 „	(12.4%)
Total	26.22 million	(100%)

The average population in the basin is 457 persons per sq. km. against 182 for India as a whole. All the districts lying in the basin have a higher than average density of population. The Saran district of Bihar has the highest density of population with 620 persons per sq. km. while the Darjeeling district in West Bengal has lowest density with 255 persons per sq. km.

7.18 According to the 1971 census, two cities in the basin have a population of more than 1 lakh each. These are Muzaffarpur and Darbhanga, both in Bihar. The main occupation of the people is agriculture and more than 91.8 per cent of the total population live in villages. 31.2 per cent of the total population is the working force.

Forests and Agriculture

7.19 Within India, only 3.0 per cent of the total geographical area of the basin is covered by forests. The culturable area constitutes more than 77.2 per cent of the total area and 88 per cent of the culturable area is cultivated annually. Practically the entire area under cultivation grows food crops. Agriculture in the basin is characterised by poor irrigation facilities. Hardly 8.6 per cent of the total area cultivated has irrigation facilities of any sort.

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*Census Paper I of 1971 (supplementary), Registrar-General (India).

Power

7.20 Of all the rivers joining the Ganga downstream of the Ghaghara on its left bank, the Kosi has got the highest hydro-power potential. According to the surveys carried out by the Central Water and Power Commission, the hydro-power potential of the Kosi is of the order of 4,742 MW at 60 per cent load factor. Almost all the sites for power projects on this river lie in Nepal and hence would require agreements with that country. According to the surveys, the Gandak has a power potential of 45.5 MW. The development of power on these rivers so far has been very meagre. The total power production so far achieved is 35 MW (installed capacity) under the Gandak and the Kosi projects. The Kosi basin has excellent prospects for the generation of enormous power.

Mineral Wealth

7.21 No mineral of any significance is found in the basin except some coal deposits in the Darjeeling district. The Coal in this district is in a powdery condition and needs to be briquetted before it can be used for domestic purposes or by the tea industry. Copper in the form of disseminated grains in slates and schist, is found in the Darjeeling district. The Ore has a low copper content.

Industries

7.22 As there are no minerals and agriculture is the main occupation of people, there are no big industries in the basin. Industries manufacturing agricultural implements, drugs and pharmaceuticals and other light engineering industries are located in big towns like Muzaffarpur and Darbhanga. Industries making use of agricultural produce are found in the Darbhanga, Monghyr and Muzaffarpur districts. Jute mills situated in Darbhanga and Katihar and sugar mills located in Darbhanga, Monghyr and Muzaffarpur deserve mention. The tea industry predominates in Darjeeling district.

Communications

7.23 The basin, in comparison with South Bihar, is not well served by roads or railways. However, a number of National Highways connecting Patna to Raxaul (NH 28 and 28A). Patna to Siliguri and on to Gangtok (NH 31) and NH 34 connecting Calcutta to Siliguri pass through the basin. In addition there are State highways connecting important towns. The area is served by the Northeastern Railway.

Practically all the rivers are navigable in the plains. Small country crafts ply along the river carrying men and materials.

WATER RESOURCES

Surface Water

7.24 The first assessment of surface water potential of the basin was made by the Indian Irrigation Commission (1901–03). As there were no records to show the surplus passing to the sea, reliance was placed upon a coefficient of runoff, selected with regard to the rainfall and other conditions, and to the co-efficient of actual flow, determined for other catchments. The Commission, however, cautioned that the estimates arrived at by this method must be regarded as mere rough approximations. According to the above assessment, the total annual surface flow of the Ganga below Varanasi was estimated at 325,646 m. cu. m.*

7.25 In 1949 when the assessment of the basin-wise water resources of the country was made on the basis of Khosla's formula, the annual runoffs of the Gandak and the Kosi sub-basins were estimated at 29,344 m. cu. m. and 102,922 m. cu. m. respectively.**

7.26 The Central Water and Power Commission has estimated the average annual runoff of the basin at 174,661 m. cu. m.† based on the normal rainfall in individual sub-basins. The Kosi and the Gandak contribute a major portion of the total runoff estimated. The Gandak has an estimated yield of 45,022 m. cu. m. while the Kosi yields 70,555 m. cu. m. The distribution of the individual sub-basin is given in Table 7.5.

7.27 Another estimate of the total average flows is 134,277 m. cu. m. This compares well with the figure of 134,943 m. cu. m. estimated as the average runoff from the rivers by the Bihar Irrigation Commission (According to the Bihar Irrigation Commission the total runoff of all the rivers except the minor basins between the Kosi and the Mahananda is 128,035 m. cu. m. Adding to this 7,031 m. cu. m. as the yield from the minor basins between the Kosi and the Mahananda as estimated by the Central Water and Power Commission, the total yield comes to 135,006 m. cu. m.)

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*Report of the Indian Irrigation Commission (1901-03).

**An appraisal of water resources by Dr. A. N. Khosla, UNESCO.

†Report of the technological possibilities of irrigation projects in India, Central Water and Power Commission (unpublished).

Table 7.5

Average Annual Runoff

(*m. cu. m.*)

Name of the river	Average annual runoff
1	2
Gandak	45,022
Baya	2,220
Burhi Gandak	11,965
Bagmati	13,075
Kamla	5,181
Kosi	70,555
Minor basins between the Kosi and the Mahananda	7,031
Mahananda	19,612
Total	174,661

7.28 The Gandak and the Kosi have been gauged for a number of years at Tribeni and Barahakshetra respectively. A number of gauging stations have been established since 1958.

Ground Water

7.29 The Geological Survey of India has carried out studies for assessing yield of ground water in the various sub-basins. Details of the studies are enumerated below:*

The availability of groundwater in the Deoria and Gorakhpur districts is influenced by the presence of the Ghaghara and the Great Gandak. The water-table is shallow in the vicinity of the Great Gandak river and progressively falls as one goes away from it.

In the Champaran, Darbhanga and Muzaffarpur districts, an area of approximately 10,000 km. has been surveyed. The area is underlain by alluvium of recent to subrecent age extending down to a depth of 130 to 140 m. The alluvium comprises of a succession of sand beds of varying texture mixed with silt and clay with occasional kankar. Groundwater occurs under water-table conditions in the shallow aquifers and under confined conditions in the deeper aquifers. The water-table is normally 2 to 6 m. below ground level in winter and 2 to 7 m. in summer.

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*Ground Water Resources of India, Status and Surveys, Prospects and Perspectives, Geological Survey of India (August, 1970).

An area of about 13,000 sq. km. in the Purnea and Saharsa districts has been surveyed. The area lies in the Kosi sub-basin and is underlain by alluvial clay, sand and silt of recent to subrecent age. In the western part of the districts, groundwater occurs under semi-confined conditions whereas in the eastern parts where sand beds persist vertically and laterally ground water occurs between 40 to 100 m. below ground level.

An area of about 10,000 sq. km. has been surveyed covering the whole of the Malda and West Dinajpur districts. Ground water occurs under confined conditions in areas where the older alluvium outcrops. In the rest of the area underlain by recent alluvium, ground water is found under water-table conditions.

The major part of the Darjeeling district is characterised by rugged topography and underlain by consolidated sedimentary rocks of the Himalayas. The surface runoff is very high and ground water is quickly drained off. The possibility of ground water development in the region appears to be remote.

There are good prospects for the development of ground water in the plains of North Bihar and in the Malda and West Dinajpur districts of West Bengal. No quantitative estimation of these resources has, however, yet been made.

EXISTING DEVELOPMENT

7.30 Prior to Independence the only project of importance in the basin was the Tribeni Canal taking off from the river Gandak. Work on the canal was taken up as a relief work during the great famine of 1897. The project was also considered as a part of the Gandak project which was to irrigate more than 0.8 million hectares in the Champaran, Muzaffarpur and Saran districts. The project as executed between 1901 and 1914 consisted only of an inundation canal drawing water through a head regulator on the river and commanding an area of nearly 0.115 million hectares. The canal has been improved from time to time and till 1951, it irrigated annually about 48,000 hectares.

7.31 Two smaller projects were also in existence prior to 1951, namely, the Dhaka canal taking off from the Lalbakhiya river (a tributary of the Bagmati river) completed in 1901 and irrigating an area of 6,480 hectares and the Madhuban Canal (Teur Canal) in the Champaran district taking off from the river Teur and irrigating 1,620 hectares annually.

During the Plan periods, two important projects namely the Kosi

Project and the Gandak Project to benefit the Saharsa, Purnea, Champaran, Muzaffarpur and Saran districts in Bihar and the Deoria district in Uttar Pradesh have been taken up.

Kosi Project

7.32 The Kosi Project is an irrigation-cum-flood control project taken up under the First Five Year Plan. It is expected to be completed in all respects during the Fourth Plan. The project consists of a barrage across the Kosi about 5 km. upstream of Hanumannagar in Nepal. Two flood embankments—one on each bank, have been constructed for a length of about 120 km., to check the tendency of the river to change its course and to restrict the flood damage. The Eastern Kosi Canal provides irrigation to about 0.57 million hectares in the Saharsa and Purnea districts. The project also provides for the construction of the Western Kosi Canal to irrigate about 0.31 million hectares in the Saharsa district and 12,150 hectares in Nepal, and the Rajpur Canal taking off from the Eastern Kosi Main Canal at R.D. 14.5 to irrigate an area of 0.16 million hectares in the Saharsa district. Thus the total benefits from the project will be 1.04 million hectares of irrigation in Bihar and 12,150 hectares of irrigation in Nepal. Generation of 20 MW of power on the Eastern Kosi Canal of which 10 MW will be supplied to Nepal, is also provided.

7.33 The work on the barrage and embankments was completed in 1963. These have proved to be a great boon to the flood ravaged areas in the Saharsa district. The work on the Eastern Kosi Canal is expected to be completed during the Fourth Plan period. The work on the Western Kosi Canal which involves excavation of the canal in the Nepal territory has not made much headway. However, it is expected that this canal will be completed during the Fifth Plan period. The Rajpur Canal is expected to be completed during the Fourth Plan period. Against a total irrigation benefits of 1.05 million hectares which is expected after the completion of the project including the Western Kosi Canal, irrigation potential of about 0.4 million hectares was created by 1968. The area irrigated up to 1969 was of the order of 0.24 million hectares.

Gandak Project

7.34 The Gandak Project is another important project to be undertaken in the basin during the Plan periods. An Agreement between the Government of Nepal and the Government of India in respect of this project was arrived at in 1959 and work on the project was started in 1961. The project provides for the construction of a barrage across the

Gandak at Valmiki Nagar about 760 m. below the existing Tribeni head regulator. The barrage is situated on the border of India and Nepal and will be 743 m. long and 9.81 m. above the bed level of the river. The project when completed will irrigate 1.15 million hectares in Bihar, 0.05 million hectares in Nepal and 0.27 million hectares in Uttar Pradesh. The project is expected to be completed during the Fifth Plan period.

7.35 A number of medium projects have also been undertaken in the basin. The details of all the projects so far undertaken are given below:

Table 7.6

Projects Completed and Under Construction in the Basin

Name of Project	Location (District)	Date of completion	Estimated cost (Rs. million)	Ultimate irrigation (hectares)
1	2	3	4	5
Uttar Pradesh				
(a) Completed Projects				
(i) Pre-Plan Projects		NIL		
(ii) Plan Projects				
Narayani Gandak/Pokhra Canal	Gorakhpur	1960-61	9.57	20,440
(b) Projects under Construction				
(i) Gandak Project—Western Gandak Canal	Deoria	IV Plan (Probable)	506.4	265,970
Total for Uttar Pradesh			516.17	286,410
Bihar				
(a) Completed Projects				
(i) Pre-Plan Projects				
Tribeni Canal	Champaran	1914	8.16	48,160
Dhaka Canals	N.A.	1901	0.63	6,480
Teur Canals	Champaran	1876	0.07	1,620

Table 7.6—Contd.

1	2	3	4	5
(ii) Plan Projects				
Tribeni Canal Expansion	Champaran	1956	2.98	11,330
Tribeni Canal Extension	Champaran	1962	11.20	25,130
Kamla Canal	Darbhanga	1958	3.09	15,380
Kamla Weir	Darbhanga	1969	7.78	Benefits under Kamla Irrigation
(b) Projects under construction				
1. *Kosi Project*				
Eastern Kosi Canal	Purnea and Saharsa	IV Plan (Probable)	59,570 (Irrigation Cost)	568,300
Western Kosi Canal	Darbhanga	V Plan (Probable)	196.90	324,970 (includes 12,145 hectares in Nepal)
Rajpur Canal	Saharsa	IV Plan (Probable)	68.20	160,670
2. *Gandak Project*	Champaran (Benefits in the Muzaffarpur, Saran and Darbhanga districts)	V Plan (Probable)	1,190.00	1,199,130 (included 448,800 hectares in Nepal)
3. Kamla Irrigation	Darbhanga	IV Plan	11.52	26,300
Total for Bihar			2,090.63	2,387,470
West Bengal		NIL		
Grand Total			2,606.80	2,673,880

7.36 Major and medium projects which were in existence prior to the First Five Year Plan and those so far undertaken during the Plan periods would provide, on their completion and full development, irrigation facilities to an area of about 2.7 million hectares. In the above figures are included benefits which would accrue under the Kosi Project (1.05 million hectares) and the Gandak Project (1.47 million hectares) which are still under construction. Irrigation facilities so far created from all major and medium projects (including pre-Plan schemes) is of the order of 0.4 million hectares.

7.37 In addition to major and medium projects, there are other sources like tanks, wells and tubewells providing irrigation to small areas under them. The source-wise irrigation in the basin during 1967–68 was as given below:

Table 7.7

Source-wise Irrigation

(Thousand hectares)

Source of irrigation	Area irrigated				Percentage to total area irrigated
	Uttar Pradesh	Bihar	West Bengal	Total	
1	2	3	4	5	6
Canals	0.5	175.8	15	191.3	51.1
Tanks	2.2	13.3	14.5	30.0	8.0
Wells	26.6	68.1	0.2	94.9	25.4
Other sources	1.8	48.6	7.7	58.1	15.5
Total	31.1	305.8	37.4	374.3	100.0

7.38 The Kosi and the Gandak projects will on their completion irrigate about 90 per cent of the total area expected to be brought under irrigation when all the projects so far undertaken are completed. Taking into account the percentage of kharif, rabi and perennial crops, the average delta on these projects would work out to 0.91 m. Assuming the same delta for other projects, the total water diverted for irrigating 2.7 million hectares which is expected to be brought under irrigation when all the projects so far undertaken are completed would be of the order of 24,670 m. cu. m.

7.39 In the absence of data regarding the delta obtainable under minor irrigation schemes, the same delta as obtained in the Kosi and the Gandak projects (i.e. 0.91 m.) has been adopted. The water requirements of 225,400 hectares which were irrigated under tanks and other sources during 1968–69 would be of the order of 2,060 m. cu. m.

Reservoir Losses

On the basis of assumptions detailed in para 1.33 the reservoir losses from the various schemes in the basin will be as shown on page 147.

(i) Major and Medium Schemes	— m. cu. m.
(ii) Minor Schemes (tanks)	355 m. cu. m.
Total	355 m. cu. m.

7.41 Thus, on completion and full development, the total water utilised from all major, medium and minor irrigation schemes under operation and construction in 1968–69 would be of the order of 27,074 m. cu. m. (26,006 m. cu. m. of surface + 1,068 m. cu. m. of ground).

Although the present water requirement of the industries in the basin is insignificant, this aspect has to be kept in view while planning future projects.

FUTURE DEVELOPMENT

7.42 The average surface water potential of the basin is of the order of 134,277 m. cu. m. Surface water utilisation from all the projects so far completed or under construction is of the order of 26,006 m. cu. m. leaving an enormous quantity of water of 108,271 m. cu. m. for future development.

7.43 The projects contemplated in the basin for irrigation and for the generation of hydro-power in the future are given below:

Table 7.8

Future Projects in the Basin

Name of scheme	Ultimate irrigation (million hectares)	Power (MW)
1	2	3
Kurule (Sun Kosi)	—	710
Benighat (Sun Kosi)	—	230
Gras Dam (Kamla)	0.130	—
Nonethore (Bagmati)	0.012	—
Chapti Dam (Burhi Gandak)	0.095	—
Total	0.237	940

7.44 These projects would irrigate 0.237 million hectares and will utilise hardly 24,670 m. cu. m. (with a delta of 0.91 m. and evaporation losses at 20% of water diverted), leaving a very large surplus of surface water unutilised.

FLOODS, WATERLOGGING AND DRAINAGE

7.45 Almost all the rivers of north Bihar rise in the Himalayan ranges and during the monsoon bring down enormous quantities of water and silt. As they enter the plains their slopes get reduced, the silt load carried by them is dropped and as a consequence, the rivers have a tendency to spill their banks and to shift their courses. North Bihar has a very serious flood problem, which is accentuated when the Ganga is also in flood and the water of its tributaries are prevented from entering into it and get backed up. The flood affected areas can be broadly grouped under the following three zones:

(i) Gandak Zone.
(ii) Central or Adhwara Zone.
(iii) Kosi Zone.

The Gandak Zone

7.46 The Gandak has been provided with marginal embankments on both banks for a considerable distance from its outfall into the Ganga. Even prior to 1954 embankments totalling 375 km. were constructed along its banks in the Saran, Champaran and Muzaffarpur districts. After 1954 the few gaps existing in the embankments have also been closed. Thus the flood ravage of the Gandak has more or less been controlled.

The Burhi Gandak can also be considered as being in the Gandak Zone. This river also has been embanked for a considerable length and the flood problem which at one time used to be very serious has been more or less controlled.

The Central or the Adhwara Zone

7.47 The Adhwara Zone has two main river systems namely the Bagmati and the Kamla. Between them there is a network of water-laced channels, traversing the north eastern parts of the Muzaffarpur district and the western parts of the Darbhanga district. The gradients of these rivers in the upper reaches are very steep and they bring down a heavy charge of silt from their catchments. Lower down when the gradients become flatter, the silt is deposited. This results in the river spilling over their banks to cause extensive flooding and a frequent shifting of their courses. To control the flood problem of the Bagmati, the Bihar Government has constructed embankments on the river over a distance of about 90 km. on its right bank from Hayaghat to Karachin and for a distance of about 70 km. on its left bank from the Hayaghat to Sirsia. A number of groynes in the spill channels of the river have also been constructed to check erosion.

7.48 The problems of the Kamla river are similar to those of the Bagmati. The Bihar Government has formulated a comprehensive flood control scheme for this river, which contemplates embankments along both banks from the village of Mirchia down to the confluence with the Kosi. On the upstream side of Mirchia, there is no flood problem as the river is confined between its banks.

The Kosi Zone

7.49 The Kosi is the most treacherous of the north Bihar rivers so far as floods are concerned. The river has a marked tendency to change its course and during the last 200 years it has shifted in a westward direction over a breadth of 112 km. The river deposits coarse silt brought down from the Himalayas on vast stretches of cultivated areas and renders them unfit for cultivation. When the river is in flood, the entire area is a vast sheet of water sometimes extending 25 to 30 kms. in width. The Bihar Government took up the construction of the Kosi Project during the First Plan for alleviating the flood ravages. The project has a barrage across the river and two flood embankments, one on either bank, for a distance of nearly 120 km. The embankments aim at checking the westward shift of the river and also at confining the flood problem to the territory lying between them. The barrage and the embankments were completed by 1963 and have proved a great boon to the areas affected by the annual floods.

7.50 The Mahananda has no serious flood problem. However when there is some spill, the flooded area is rendered temporarily unfit for cultivation, because of the deposit of coarse silt.

7.51 There are no reports of waterlogging due to irrigation in the basin. Local depressions called Chaurs which are filled with water during the monsoons, do not get drained quickly and cause some waterlogging.

SOIL CONSERVATION

7.52 As mentioned in paragraphs 7.23 and 7.45, most of the rivers joining the Ganga on its left bank downstream of the Ghaghara have a considerable part of their catchments in the Himalayas. The mountains are steep and deforestation and landslides due to earthquakes cause enormous quantities of material to find their way into the rivers, which transport them down to the plains, causing widespread flooding and the shifting of river courses.

Soil conservation measures need to be taken up urgently in the Himalayan catchments of these rivers in co-operation with the Nepal Government.

SALIENT FEATURES OF THE BASIN OF THE RIGHT BANK TRIBUTARIES EAST OF SON

(i) Source	The Pun-Pun	In the Chottanagpur plateau in Bihar (Latitude 24°31′ N, Longitude 84°9′E).
	The Kiul	East of Khajuri in the Chottanagpur plateau (Latitude 24°23′N, Longitude 86°10′E).
	The Man	In the Kharagpur hills (Latitude 25°9′N, Longitude 86°24′E).
	The Chandan	Near Deoghar in the Santhal Parganas district (Latitude 24°37′N, Longitude 86°34′E).
	The Gerua	Near Ramgarh in the Santhal Parganas district (Latitude 24°35′N, Longitude 87°13′E).
	The Gumani	Near Daman-i-koh in the Santhal Parganas district (Latitude 24°39′N, Longitude 87°28′E).
	The Baghmari	Near Daman-i-koh in the Santhal Parganas district (Latitude 24°35′N, Longitude 87°26′E).
	The Pagla	North-East of Gopikandar in the Santhal Parganas district (Latitude 24°28′N, Longitude 87°36′E).
	The Dwarka	Near Baramasia in the Birbhum district (Latitude 24°11′N, Longitude 87°25′E).
	The Ajay	South-west of Chakkai in the Santhal Parganas district (Latitude 24°30′N, Longitude 86°18′E).
	The Damodar	South-west of Chandwa in the Palamau district (Latitude 23°39′N, Longitude 84°41′E).
	The Rupnarayan	Near Bagalia in the Purulia district (Latitude 23°26′N, Longitude 86°33′E).
	The Haldi	Near Nikursini in the Midnapore district (Latitude 22°2′N, Longitude 87°17′E).

(ii) Length	The Pun-Pun	200 km.	124 miles
	The Kiul	111 km.	69 miles
	The Man	40 km.	25 miles
	The Chandan	118 km.	73 miles
	The Gerua	86 km.	53 miles
	The Gumani	100 km.	62 miles
	The Baghmari	120 km.	75 miles
	The Pagla	57 km.	35 miles
	The Dwarka	134 km.	83 miles
	The Ajay	276 km.	171 miles
	The Damodar	519 km.	322 miles
	The Rupnarayan	254 km.	158 miles
	The Haldi	95 km.	59 miles

(iii)	Drainage area	Bihar	61,261 sq. km.	23,653 sq. miles
		West Bengal	35,843 sq. km.	13,838 sq. miles
		Total	97,104 sq. km.	37,491 sq. miles
(iv)	Population (1971 census)		33·27 millions	
(v)	Density of population		342 per sq. km.	886 per sq. mile
(vi)	Average annual runoff of the basin		45,145 m.cu.m.	36.6 MAF

		Thousand hectares	Thousand acres
(vii)	Culturable area (1967-68)	6,729	16,623
(viii)	Net area sown (1967-68)	4,663	11,523
(ix)	Gross area sown (1967-68)	5,474	13,527
(x)	Net irrigated area (1967-68)	1,872	4,626
(xi)	Gross irrigated area (1967-68)	2,014	4,977
(xii)	Ultimate irrigation by major and medium projects under operation and construction in 1968-69	1,488	3,677

			m. cu. m.	MAF
(xiii)	Water utilisation including reservoir losses on completion and development from major, medium and minor projects under operation and construction in 1968-69	Surface water	28,366	22.99
		Ground water	1,552	1.26
	Total		29,918	24.35

CHAPTER VIII

THE BASIN OF THE RIGHT BANK TRIBUTARIES EAST OF THE SON

The Basin

The basin extends over an area of 97,104 sq. km., and lies between east longitudes 84°5′ to 88°27′ and north latitudes 21°35′ to 25°42′. Lying to the south of the Ganga, the basin covers practically the whole of south Bihar and the southern districts of West Bengal lying to the west of the Bhagirathi and Hooghly rivers. The state-wise distribution of the drainage area is given below:

Bihar	61,261 sq. km.
West Bengal	35,843 sq. km.
Total	97,104 sq. km.

8.2 The basin is bounded on the north by the Ganga, on the east by the Bhagirathi and the Hooghly rivers, on the south by the ridge separating it from the Subarnarekha sub-basin and the Chhota Nagpur plateau and on the west by the ridge separating it from the Son basin. The basin is irregular in shape and has a maximum length of 455 km. in the east-west direction and a maximum width of 405 km. in the north-south direction.

THE RIVER SYSTEM

8.3 The more important of the rivers joining the Ganga east of the Son are the Pun-Pun, the Kiul, the Dwarka, the Ajay, the Damodar, the Rupnarayan and the Haldi. Other rivers are the Man, the Chandan, the Gerua, the Bheno and the Koa, joining the Ganga in Bihar territory and the Gumani, the Bagmari and the Pagla joining it in West Bengal. The drainage areas of the individual river systems are given in Table 8.1.

Table 8.1

Drainage Area of the Various River Systems

(sq. km.)

Name of the river system	Drainage area
1	2
Pun-Pun	8,530
Kiul	16,580
Man	950
Chandan	3,490
Gerua	1,920
Bheno and Koa	860
Gumani	1,560
Bagmari	2,190
Pagla	630
Dwarka	8,850
Ajay	6,050
Damodar	25,820
Rupnarayan	8,530
Haldi (Kasai)	10,210
Other misc. streams	934
Total	97,104

The following paragraphs give brief description of the aforesaid rivers.

8.4 *The Pun-Pun* rises in the Chotta Nagpur Plateau in Bihar, at an elevation of 300 m. at north latitude 24°31′ and east longitude 84°9′ and joins the Ganga about 25 km. to the east of Patna after flowing in a north-easterly direction through the Gaya and Patna districts. The river has a number of tributaries joining it mostly on its right bank. Important among them are the Batane, the Madar and the Morhar. All these rivers rise in the Chotta Nagpur Plateau and are rain-fed. They flow only during the monsoon and are dry for the rest of the year. The Pun-Pun has a total length of 200 km.

8.5 *The Kiul* rises in the Chotta Nagpur Plateau at an elevation of 605 m. at north latitude 24°23′ and east longitude 86°10′. The river flows first in an easterly direction close to the southern face of the Girdeshwari hills and later in a northerly direction. It then takes a north-easterly direction up to Lakhisarai and joins the Ganga near Surajgarha in the

Monghyr district. The important tributaries of the Kiul are the Harohar, the Barnar, the Azan and the Ulai. Of these, the Harohar is the biggest and the most important. The Kiul has a total length of 111 km.

8.6 *The Man* rises in the Kharagpur hills at an elevation of 250 m. at north latitude 25°9′ and east longitude 86°24′ and flows in a north-eastern direction to join the Ganga near Ghorghat. It has a total length of 40 km.

8.7 *The Chandan* rises near Deoghar in the Santhal Parganas district of Bihar at an elevation of 250 m. at north latitude 24°37′ and east longitude 86°34′. Flowing in a northerly direction, it receives a number of tributaries like the Kudar Nalla, the Orni Nalla, the Chandan Nalla, the Kundua Nalla and the Katharia Nalla and ultimately joins the Ganga near Bhagalpur. It has a total length of 118 km.

8.8 *The Gerua* rises in the Santhal Parganas district at an elevation of 200 m. at north latitude 24°35′ and east longitude 87°13′ and for a major part of its length, forms the boundary between the Santhal Parganas and Bhagalpur districts. The Gerua joins the Ganga near Colgong. It has a total length of 86 km.

8.9 *The Bheno and the Koa* are two small streams which rise in the Santhal Parganas district and meet the Ganga near Colgong.

8.10 *The Gumani* rises in the Santhal Parganas district at an elevation of 450 m. at north latitude 24°39′ and east longitude 87°28′ and after flowing for a distance of about 50 km. in a north-easterly direction, receives a tributary viz. the Maral on its left bank. The combined stream then flows in an easterly direction for about 50 km. to join the Ganga near Farakka on the border of Bihar and West Bengal.

8.11 *The Baghmari* is formed by the confluence of three streams, namely the Kanloi, the Taroi and the Bansloi, which have their origins in the Santhal Parganas district of Bihar. The river joins the Ganga about 15 km. upstream of the offtake point of the Bhagirathi. It has a total length of 120 km.

8.12 *The Pagla* is a rain-fed nalla rising in the Santhal Parganas district at an elevation of 100 m. at north latitude 24°28′ and east longitude 87°36′ and joins the Bhagirathi near Jangipur in the Murshidabad district of West Bengal. The river has a total length of 57 km.

8.13 *The Dwarka* or *the Babla* rises at an elevation of 150 m. at north latitude 24°11′ and east longitude 87°25′ and is a continuation of the Brahmani river, which rises in the Birbhum hills and joins the Bhagirathi in the Murshidabad district. One of the important tributaries of the Dwarka is the Mor or the Mayurakshi. The Mayurakshi dam constructed across the river irrigated lands in West Bengal and Bihar. The project is one of the important major projects taken up by the West Bengal Government for controlling floods in the river and for providing irrigation to lands in the Birbhum district. Some areas in the Santhal Parganas district in Bihar also get irrigation from the project. The Dwarka has a total length of 134 km.

8.14 *The Ajay* is formed by the confluence of several small streams, namely the Kunur, the Hingla, the Jainti and the Pathro, which rise in the hills of the Santhal Parganas and Hazaribagh districts of Bihar and flows in a south-easterly direction. The river after passing through the Santhal Parganas district of Bihar and the Birbhum and Burdwan districts of West Bengal, joins the river Bhagirathi near Katwa. It has a total length of 276 km.

8.15 *The Damodar* also known as the Deonadi in its initial reaches is one of the most important rivers to join the Ganga on its right bank, east of the Son. The river has a total catchment area of 25,820 sq. km. and drains areas in the Ranchi, Hazaribagh, Dhanbad and Santhal Parganas districts of Bihar and the Bankura and Burdwan districts of West Bengal. The Damodar rises in the south-east corner of the Palamau district of Bihar at an elevation of 600 m. at north latitude 23°39′ and east longitude 84°41′ and after flowing for about 40 km., it forms the boundary between the Hazaribagh and Ranchi districts. It then enters Hazaribagh district and flows in an easterly direction for about 145 km. and receives an important tributary, namely the Bokaro. The river then enters Dhanbad district and, while flowing through this district, receives the Barakar. The Damodar then enters West Bengal and flows through the Bankura and Burdwan districts. The important tributary, which joins the river in the Bankura district is the Sali Nadi. The river flowing past the town of Burdwan turns south and ultimately joins the Hooghly near Fulta point, after flowing for a total length of 541 km. The river used to flood large areas in the lower reaches in West Bengal causing widespread damage to property and agriculture. The Damodar Valley Project consisting of four dams and a barrage on the main river and its tributaries was taken up immediately after Independence to provide relief from floods. The project, in addition to controlling floods, provides irrigation facilities to about 0.365 million hectares in West Bengal.

8.16 *The Rupnarayan* rises in the Tilabni hills in Bihar at an elevation of 405 m. at north latitude 23°26′ and east longitude 86°33′ and flows in a tortuous south-easterly course through Bankura district before entering Burdwan district. The Silai Nadi joins the Rupnarayan in Midnapore district. After a further course of about 80 km. forming the boundary between the districts of Midnapore, Hooghly and Howrah, the river joins the Hooghly near Nurpur immediately downstream of the confluence of the Damodar. The Rupnarayan is tidal for almost its entire course. The river has a total length of 254 km.

8.17 *The Haldi* river joins the Hooghly below the confluence point of the Rupnarayan. The Kasai, its chief affluent, has its origin in Bihar and after leaving that State, it flows through the Bankura and Midnapore districts in West Bengal before joining the Haldi. The Kangsabati Project, which is expected to irrigate 0.385 million hectares in the Bankura, Midnapore and Hooghly districts, is situated in this sub-basin.

CLIMATE

8.18 The Bihar portion of the basin can be broadly divided into the Chhotanagpur Plateau and the plains. In the plains the summer temperature rises as high as 49°C and the winter temperature touches 2°C. The plateau has a comparatively moderate climate. As far as West Bengal is concerned, the region can be divided into the North Temperate Zone lying to the north of the Tropic of Cancer and the equatorial zone to the south of it. The climate in the equatorial zone is equitable due to the proximity of the Bay of Bengal and a network of canals, beels and tanks.

8.19 The rainfall in the region is caused by the south-west monsoon from June to September. In West Bengal, however, the rains begin early in May and extend up to the end of October. The average annual rainfall and the average rainfall during June-September in different districts lying in the basin are given in Table 8.2.

8.20 There are a number of rain-gauge stations in the basin. Data regarding the number of rain-gauge stations in the individual sub-basins is not available except for the Damodar sub-basin. There are 37 rain-gauge stations in the Damodar sub-basin giving rain-gauge dispersion of one station per 700 sq. km. The distribution of the stations is not even and their number is also not sufficient. Establishment of a few more rain-gauges to obtain a balance distribution over the entire basin is suggested.

Table 8.2

Rainfall in the Basin

(mm)

District	Average annual rainfall	Average monsoon rainfall (June-September)
1	2	3
Bihar		
Palamau	1,335	1,140
Hazaribagh	1,258	1,042
Patna	992	863
Gaya	1,151	1,002
Monghyr	1,206	1,009
Bhagalpur	1,166	946
Santhal	1,377	1,106
Ranchi	1,483	1,209
Dhanbad	1,311	1,074
West Bengal		
Murshidabad	1,349	1,001
Birbhum	1,285	1,000
Burdwan	1,351	1,019
Howrah	1,630	1,152
Hooghly	1,520	1,098
Bankura	1,320	1,028
Midnapore	1,539	1,138
Purulia	1,363	1,103

Source: IMD—Monthly and Annual Normals of rainfall and of rainy days (1901 to 1950).

There are three departmental and three agro-meteorological observatories of the India Meteorological Department within the basin.* The departmental observatories are located at Gaya, Sabaur and Asansol and the agro-meteorological observatories are at Patna, Sabaur and Chinsura.

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*Evaporation Data (India), India Meteorological Department (April, 1970).

SOILS

8.21 No detailed soil survey of the basin has yet been made. However, the general data regarding the soils of India indicates that mainly alluvial, laterite, red and yellow, red sandy soils and deltaic alluvium occur in the basin. The principal soil types found in the various districts lying in the basin are given below:*

Table 8.3

Soils in the Basin

District	Type of soil
1	2
Bihar	
Palamau	Red and yellow
Hazaribagh	Red, yellow and alluvial
Patna	Alluvial
Gaya	Red, yellow and alluvial
Monghyr	Alluvial and calcareous alluvial
Bhagalpur	Alluvial and red sandy
Santhal Parganas	Laterite, alluvial and red and yellow
Ranchi	Red sandy and red and yellow
Dhanbad	Red sandy and red and yellow
West Bengal	
Murshidabad	Alluvial
Birbhum	Laterite and red and yellow
Burdwan	Laterite, red and yellow and alluvial
Howrah	Alluvial
Hooghly	Alluvial
Bankura	Laterite, red sandy and red and yellow
Midnapore	Laterite, alluvial, red and yellow and deltaic alluvium
Purulia	Red sandy, red and yellow and mixed red and black

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*Indian Crop Calendar, Ministry of Food, Agriculture, Community Development and Cooperation (1967).

LAND USE AND AGRICULTURAL PRACTICES

8.22 The land use details in the basin for the year 1967–68 are given below:

Table 8.4

Land Use Details in the Basin

(Thousand hectares)

Item	State		Total
	Bihar	West Bengal	
1	2	3	4
Geographical area	6,126	3,584	9,710
Reporting area	6,071	3,572	9,643
Area under forests	1,258	345	1,603
Area not available for cultivation	857	454	1,311
Culturable area	3,956	2,773	6,729
Uncultivated culturable area	1,532	534	2,066
Net area sown	2,424	2,239	4,663
Area sown more than once	586	225	811
Total cropped area	3,010	2,464	5,474
Net irrigated area	919	953	1,872
Gross irrigated area	1,053	961	2,014
Percentage of net area sown to culturable area	61.3	80.7	69.3
Percentage of net irrigated area to culturable area	23.2	34.4	27.8
Percentage of net irrigated area to net sown area	37.9	42.6	40.1

The head reaches of most of the rivers lie in forested areas. More than 16% of the total area is under forests. Nearly 69.8% of the total geographical area is culturable and of the culturable area of 6.73 million hectares, an area of 4.7 million hectares i.e. 69.3% is cultivated annually. A characteristic feature of agriculture in the region is the high percentage of irrigated area. Nearly 40.1% of the cultivated area is provided with irrigation facilities. Minor irrigation sources provide the bulk of the irrigation and cover nearly 59% of the total area irrigated.

Agriculture, whether under irrigated or unirrigated conditions, is dominated by food crops. Under irrigated conditions, paddy is by far the most important crop. Out of a total irrigated area of 2.0 million hectares during 1967–68, paddy covered 1.7 million hectares (85%). Rabi crops like wheat and barley cover 5.8% of the total area irrigated. Tte details of the irrigated crops during 1967–68 are given in Table 8.5.

Table 8.5

Irrigated Crops in the Basin

(Thousand hectares)

Name of crop	State				Total for the basin	
	Bihar		West Bengal			
	Area	Percentage to total	Area	Percentage to total	Area	Percentage to total
1	2	3	4	5	6	7
Rice	851.1	80.8	865.4	90.1	1,716.5	85.2
Wheat	94.8	9.0	13.2	1.4	108.0	5.4
Barley	7.5	0.7	1.1	0.1	8.6	0.4
Gram	11.1	1.0	—	—	11.1	0.5
Sugarcane	15.0	1.4	9.6	1.0	24.6	1.2
Other food crops	68.0	6.6	71.4	7.4	139.4	7.0
Total food crops	1,047.5	99.5	950.7	100.0	2,008.2	99.7
Non-food crops	5.5	0.5	0.3	—	5.8	0.3
All crops	1,053.0	100.0	961	100.0	2,014.0	100.0

Crop Seasons

8.23 The two crop seasons are the kharif and the rabi. The rabi plays an insignificant role, and the Kharif is more or less the main crop season in the basin. In West Bengal, rainfall starts in April-May and extends up to the end of October. Summer paddy is sown in January-February, making use of winter rainfall and is harvested in April-May. The autumn paddy (locally known as Aman paddy) is the most important crop and is sown in May-June and is harvested by the end of November or early in December. In Bihar portion also, the same pattern prevails except that rice is harvested in October or early November.

REGIONAL ECONOMY

Population

8.24 On the basis of the 1971 Census* and on the percentage of the area of each district lying within the basin to the district as a whole, the total population in the basin is about 33.27 million, of which 17.95 million (54%) live in Bihar and the remaining 15.32 million (46%) in West Bengal. The average density works out to 342 persons per sq. km. against 182 for India as a whole. Howrah district in West Bengal has the highest density of population with 1,625 persons per sq. km. while the Palamau district in Bihar has the lowest density with 118 persons per sq. km.

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*Census Paper I of 1971 (Supplementary), Registrar-General (India).

8.25 There are four cities with a population of more than one lakh each according to the 1971 census. These are Gaya in Bihar and Burdwan, Kharagpur and Asansol in West Bengal. As in the other parts of the Ganga basin, the main occupation of the people in this region is agriculture. However, in the industrial and mining belts extending from Dhanbad and Hazaribagh in Bihar to the Howrah district in West Bengal, urbanisation has been more conspicuous and a good percentage of the people in these parts pursue occupations other than agriculture.

Forests & Agriculture

8.26 Forests occupy more than 16.6% of the total area. These are confined to the Hazaribagh, Palamau, Santhal Parganas and Ranchi districts of Bihar and to some extent to the Bankura and Midnapore districts of West Bengal. State-wise, 20.7% of the area lying in Bihar is under forests while it is only 9.7% in West Bengal. The culturable area constitutes 69.8% of the total area and 69.3% of the culturable area is cultivated annually. Practically all the cultivated area is under food crops. A characteristic feature of the cultivation in this region is that a very high percentage (40.1%) of the area cultivated annually has irrigation facilities. Irrigation in Bihar is predominantly through minor schemes.

Power

8.27 Except the Damodar, none of the rivers has any hydro-power potential. Even in the case of the Damodar, the hydro-power potential is comparatively small. The installed capacity under the Maithon, the Panchet hill, the Konar and the Tilaiya dams under the Damodar Valley Project is of the order of 104 MW only.

The generation of thermal power has, to a large extent, overcome the lack of hydro-power potential in the region which has a fair number of major industries. There are a number of thermal stations in the region. These are shown in Table 8.6.

Table 8.6

Thermal Stations in the Basin

Name of the Thermal Station	Location	Installed capacity (MW)
1	2	3
Patratu—Stage I	Hazaribagh	400
Patratu—Stage II	„	220
Bokaro	„	225
Chandrapura—Stage I, II & III	„	660
Durgapur—Stage I & II	Burdwan	290
Durgapur Cokeoven—Stage I & II and Extensions	„	435
Santaldih	Purulia	480
Total		2,710

Mineral Wealth

8.28 The important minerals found in the basin are given below:*

Coal: In the Dhanbad, Hazaribagh and Santhal Parganas districts of Bihar and the Burdwan, Birbhum and Bankura districts of West Bengal. The Jharia coal mines in Dhanbad and the Raniganj coal mines in Burdwan are well-known. The total coal reserves in Bihar and West Bengal are estimated to be of the order of 33,530 million tonnes.

Mica: In the eastern parts of the Gaya district and in the Hazaribagh, Monghyr and Bhagalpur districts of Bihar, which is the richest mica bearing State in India.

Limestone: In the Palamau, Hazaribagh and Ranchi districts of Bihar and the Purulia district of West Bengal.

Copper: In the Hazaribagh district.

Bauxite: In the Ranchi and Palamau districts.

China clay: In the Santhal Parganas and Bhagalpur districts of Bihar and the Bankura and Birbhum districts of West Bengal.

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*Techno-Economic Surveys of Bihar and West Bengal, NCAER.

Fire clay: Occurs abundantly along the coal seams in the coal fields of Bihar.

Industries

8.29 With the availability of raw materials like coal and iron ore (from neighbouring territories) and power and water, many major industries have been established in the Hazaribagh, Ranchi and Dhanbad districts of Bihar and the Burdwan, Bankura, Birbhum, Hooghly and Howrah districts of West Bengal.

Important factories established in the Bihar region are the Fertilizer Factory at Sindri and the Explosives Factory in Gomia in Hazaribagh district. The Bokaro which will be the biggest steel plant of India, is located in the Dhanbad district of Bihar. So far as West Bengal region is concerned, there are a number of major industries located in the basin. Important ones are Steel Plants at Durgapur, Kulti and Burnpur, the Chittaranjan Locomotive Factory, the Cable Factory at Rupnarayanpur and the Mining Equipment Factory at Durgapur. In addition there are other medium sized industries in the region like the glass and ceramic industries and the rubber tyre and rubber products industries.

There are many industries based on the agricultural produce of the region. Rice mills have been set up in the rice-growing districts of Bankura, Burdwan, Birbhum, and Hooghly. There are oil mills in the Birbhum, Howrah and Burdwan districts. Among the agro-based industries, mention may also be made of the jute and textile industries situated in the Hooghly and Howrah districts.

Among the forest based industries, the saw mills in the Midnapore district may be mentioned.

Many light engineering industries are situated in the Burdwan, Hooghly, Bankura, Purulia and Birbhum districts.

The coal mining industry in the Dhanbad and Burdwan districts is very important.

Communications

8.30 With a large number of major and medium sized industries established in the region, it is only to be expected that communications in the area are good. There are a number of National Highways passing through the region. National Highway No. 2 connecting Delhi-Calcutta, National Highways 31–33 connecting Ranchi-Patna and National Highway No. 6 connecting Calcutta-Kharagpur all pass through the region. Many state and district highways also serve the area. The region is served by the Eastern and South-Eastern Railways.

Almost all the rivers, when there is adequate water in them, are navigable in the plains. The Damodar Canal taking off from the Durgapur Barrage also provides navigation.*

WATER RESOURCES

Surface Water

8.31 The first assessment of the surface water potential of the basin was made by the first Indian Irrigation Commission. As there were no records to show the surplus passing to the sea, reliance was placed upon a co-efficient of runoff, selected with regard to the rainfall and other conditions, and to the co-efficient of actual flow, determined for other catchments. The Commission, however, cautioned that the estimates arrived at by this method must be regarded as merely rough approximations. According to the above assessment, the total annual surface flow of the Ganga below Varanasi was estimated at 325,646 m. cu. m.**

8.32 In 1949 when the assessment of the basin-wise water resources of the country was made on the basis of Khosla's formula, the annual run-off of the Ganga, east of the Son up to the international border, was estimated at 165,077 m. cu. m.†

8.33 The average water potential of the basin, as estimated by the Central Water & Power Commission on the basis of Strange's Co-efficient for average catchments, is of the order of 45,145 m. cu. m.‡ The approximate sub-basin-wise distribution is given in Table 8.7.

8.34 The Damodar and its tributaries have been gauged at many places for a number of years from 1945 onwards. Prior to the construction of dams by the Damodar Valley Corporation, the Damodar river was gauged at Sudamdih (Panchet hill dam site), the Konar river at Hurlong (Konar dam site) and the Barkar river at Barhi (Tilaiya dam site) and Chirkunda (Maithon dam site). After the construction of these dams, gauge and discharge observations have been continued just downstream of the dams.

8.35 A number of gauge and discharge sites have been established since 1958.

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*Navigable Waterways of India, Central Water & Power Commission (1961).

**Report of the Indian Irrigation Commission (1901-03).

†An appraisal of water resources by Dr. A. N. Khosla, UNESCO.

‡Report of the technological possibilities of irrigation projects in India, Central Water & Power Commission (unpublished).

Table 8.7

Average Annual Runoff

Sub-basin	Average annual runoff m.cu.m.
1	2
Pun-Pun	3,577
Kiul	5,797
Man	493
Chandan	1,604
Gerua	864
Bhena & Koa	493
Gumani	864
Bhagmari	1,233
Pagla	370
Dwarka	4,687
Ajay	3,207
Damodar	12,211
Rupnarayan	4,441
Haldi	5,304
Total	45,145

Ground Water

8.36 The Geological Survey of India has carried out studies for assessing yields of ground water in the various sub-basins. Details of the studies are enumerated as follows.*

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*Ground Water Resources of India, Status and Surveys, Prospects and Perspectives, Geological Survey of India, (August, 1970).

In the Patna district ground water occurs under confined conditions. Depth of water below ground level, as measured in open wells, varies from 2 m. to 10 m. A large number of heavy duty tubewells have been sunk in the district for irrigation purposes.

An area of about 2,300 sq. km. has been surveyed in the Monghyr and Bhagalpur districts. Ground water occurs both in confined and water-table conditions. Depth of water varies from 1.5 m. to 4 m. below ground level.

The areas surveyed in the Ranchi, Hazaribagh, Santhal Parganas and Dhanbad districts cover the hard rock areas of the Damodar, the Ajay and the Kasai water-sheds. Ground water occurs under water-table conditions in the weathered residium of various pre-cambrian metamorphites and circulates through weak structural planes. The average depth to water is 5 m. to 8 m. below the ground level. The water is mostly used for domestic and small-scale irrigation.

In the Murshidabad district, ground water occurs in a thick zone of saturation within the alluvium and exists under water-table conditions.

The greater part of Birbhum district is covered by old alluvium and laterite except in the west where ancient crystalline and Rajmahal traps occur. In the extreme south-west sedimentary rocks of the Gondwana age outcrop. In the hard rock areas, the water-table rests at 3 m. to 8 m. below ground level and only small-scale withdrawal of ground water is feasible through open wells. The belt occurring along the Ajay river is the most promising area for heavy duty tubewells.

The eastern part of the Burdwan district covering the Trans Damodar, the Ajay and the Bhagirathi areas consists of recent alluvium and the granular fills in the alluvial soil are saturated with ground water. The entire area holds out promise for ground water development.

The western and middle parts of the Bankura district have archaean crystalline rocks and laterite and older alluvium of Pleistocene age respectively. Large-scale development of ground water in these regions may not be feasible. The eastern parts of the district consists of recent alluvium comprising a succession of sands, varying in texture from coarse to fine, clay and silt. This area holds promise for ground water development. A number of flowing tubewells (auto tubewells) exist along both the banks of the Dwarakeswar, the Jaipanda and the Silai rivers.

In the crystalline rocks of the western part of the Midnapore district, ground water occurs under water-table conditions. In the central part of the district which is underlain by a fairly thick succession of tertiary and quarternary sediments comprising sand, silt, clay and occasional streaks of lignite, ground water occurs under both confined and unconfined conditions. The depth to water level varies from 3 m. to 17 m. In the eastern part of the district, alluvial deposits formed by the Kasai and the Rupnarayan are located and are suitable for ground water development. In recent years, a large number of tubewells have been constructed in the area.

Howrah and Hooghly districts are situated between the Hooghly river in the east and the Damodar and the Rupnarayan rivers on the west and south. The Damodar river along with its tributaries has left pockets of thick sand in relict meander deposits. These sand pockets are geo-hydrologically important as they act as a re-charge zone for the adjacent areas. The water-table rests at depth ranging from 1.5 m. to 5 m. below the land surface.

Almost the entire area of the Purulia district is underlain by the archaean crystalline rocks which are generally weathered down to 25 m. to 30 m. Ground water occurs under water-table conditions and is tapped by open wells generally 9 m. to 12 m. deep with water levels lying between 5 m. to 8 m. from the ground level. The development of ground water by tubewells is not feasible. However, small-scale development by means of large diameter open wells is possible.

It would be seen, from the above paragraphs, that substantial ground water development is possible in the plains, in the Patna, Gaya, Monghyr and Bhagalpur districts in Bihar and the Howrah, Hooghly, Burdwan, Birbhum districts and the eastern parts of the Bankura and Midnapore districts in West Bengal. Already large-scale tubewell development has taken place in these districts. A quantitative assessment of ground water in the region is yet to be made.

EXISTING DEVELOPMENT

8.37 In the pre-plan period the only irrigation projects of importance were the Midnapore Canal, the Eden Canal and the Damodar Canal, all in West Bengal. No major or medium schemes were constructed in Bihar.

Eden Canal

8.38 The Eden Canal was perhaps the first canal to be constructed in the region. It was intended to improve the fresh water supply to the Burdwan and Hooghly districts which were suffering from a very severe epidemic fever attributed to the stagnant and insanitary condition of old river beds and minor drainage lines. Constructed in 1881, it takes off from the Damodar about 12 km. upstream of Burdwan town. Irrigation from the canal gradually developed and by 1890, most of its water was used for irrigation. The area irrigated from it at present is 16,190 hectares.

Midnapore Canal

8.39 The Midnapore Canal, completed in 1889, takes off from the weir across the Kasai river and carriers a head discharge of 37.77 cumecs. An area of 49,780 hectares is irrigated annually under this canal.

Damodar Canal

8.40 The Damodar Canal, completed in 1935, takes off from the weir across the Damodar further upstream of the Eden Canal. It carries a head discharge of 56.63 cumecs and irrigates an area of 72,850 hectares annually.

With the beginning of the Plan era in 1951, there has been a spurt in irrigation activity in the region. Five major projects have been undertaken on the various rivers. These are the Damodar Valley, the Mayurakshi, the Kangsabati, the Chandan and the Badua Projects. The following paras give brief descriptions of the above projects.

Damodar Valley Project

8.41 The Damodar Valley Project, as envisaged by Mr. Voorduin, was a multipurpose project to afford flood control, to generate power and to provide irrigation facilities to about 0.308 million hectares in West Bengal by constructing eight dams in the Damodar sub-basin with one barrage. However, it was later decided to have only four dams, namely the Maithon, the Panchet hill, the Tilaiya and the Konar and a barrage with irrigation canal system to supply water to 0.417 million hectares. With the increase in the demand for water by industries, irrigation supplies were reviewed from time to time and the project at present provides irrigation to 0.365 million hectares. The salient features of the four dams are given in Table 8.8.

The Durgapur Barrage from where irrigation starts was completed in 1956. The barrage is the lower-most of the structures across the Damodar within the Damodar Valley Corporation limits and is 692 m. long and nearly 12 m. above the bed level of the river. Two canals take off from the barrage to provide irrigation to 0.365 million hectares in the Burdwan, Hooghly, Howrah and Bankura districts. The work on this project is expected to be completed during the Fourth Plan.

Initial development of irrigation under the project was slow due to the reluctance of farmers to take water on account of the imposition of water rates and the absence of field channels. With the passage of time the reluctance of the farmers has lessened and since West Bengal Government has taken steps to construct field channels, the development of irrigation

Table 8.8

Salient Features of the Various Dams Under the DVC Project

Salient features	Konar	Maithon	Panchet hill	Tilaiya
1	2	3	4	5
Name of the river	Konar	Barakar	Damodar	Barakar
Type of dam	Earth dam with concrete spillway	Earth dam with concrete spillway	Earth dam with concrete spillway	Concrete
Length: (metres)	Earth dam 3549 Spillway 110	994	2545	366
Maximum height	49 m above river bed	49 m above river bed	45 m above river bed	30 m above river bed
Gross storage capacity (m.cu.m.)	337	1,357	1,497	395
Live storage capacity (m.cu.m.)	276		1,307	321
Benefits Power	Not finalised	Designed primarily for flood control Power—60 MW	Designed primarily for flood control Power—40 MW	Power—4 MW
Cost (Rupees million)	97.5	179.7	191.4	37.1
Date of start	1950	1951	1952	1950
Date of completion	1955	1958	1959	1953

Source: Central Water & Power Commission—Irrigation & Power Project (1970).

has picked up. During 1968, a total area of 0.307 million hectares was irrigated.

Mayurakshi Project

8.42 The Mayurakshi Project comprises a masonry dam, 640 m. long and 47 m. high, across the river Mayurakshi at Massanjore in the Santhal Parganas district of Bihar, about 42 km. from Bihar-West Bengal border. The reservoir has a gross storage capacity of 617 m. cu. m., of which 555 m. cu. m. is the live storage. The canal system starts from the Tilpara Barrage about 32 km. downstream of the dam. The project provides irrigation facilities to 0.247 million hectares in the Birbhum district of West Bengal. A canal taking off directly from the dam provides irrigation to 10,110 hectares in the Santhal Parganas district of Bihar. The work on the project started in 1946 was completed in 1956. The work on the construction of field channels is in progress and is expected to be completed during the Fourth Plan. During 1969, an area of 0.224 million hectares was irrigated under the Mayurakshi Project.

Kangsabati Project

8.43 The Kangsabati Project envisages an earth dam across the rivers Kangsabati and Kumari in the Kasai sub-basin upstream of their confluence near Ambikapur in the Bankura district. The dam has a maximum height of 41 m. and a gross storage capacity of 1,135 m. cu. m. of which 987 m. cu. m. is the live storage. The project on completion is expected to irrigate 0.385 million hectares in the Bankura, Midnapore and Hooghly districts. The work on the project started in 1956 but due to paucity of funds, progress was very slow. However, during recent years the tempo of work has picked up and the project is expected to be completed during the Fourth Plan.

Chandan Project

8.44 The project provides for an earth dam across the river Chandan near village Lakhimpur in the Bhagalpur district of Bihar. The maximum height of the dam is 40 m. and its length 1,570 m. The reservoir has a live storage capacity of 136 m. cu. m. Irrigation under the project will start from the pick-up weir downstream of the dam and an area of 40,150 hectares will be brought under irrigation. The project is expected to be completed by the end of the Fourth Five Year Plan.

Badua Project

8.45 The work on the Badua Project started in 1958 was completed in 1966. The Project provides irrigation to 42,490 hectares in Bihar. It consists of an earth dam across the river Badua, a tributary of the Chandan, at Hanuman Pehar in the Bhagalpur district. The dam has a length of 473 m. and a maximum height of 42 m. The reservoir has a live storage capacity of 110 m. cu. m.

8.46 A number of medium projects have been undertaken both in Bihar and West Bengal from 1951 onwards, and many of them have already been completed and are in operation. The details of all the major and medium projects under operation and construction in the basin are given in Table 8.9.

Table 8.9

Projects Completed and Under Construction in the Basin

Name of Project	Location (District)	Date of completion	Estimated cost (Rs. million)	Ultimate area irrigated (Hectares)
1	2	3	4	5
Bihar				
(a) Completed Projects				
(i) Pre-Plan Projects			NIL	
(ii) Plan Projects				
Khajia—Phase I	Bhagalpur	1959	2.21	19,020
Chandan—Phase I	,,		4.20	
Mayurakshi L.B. Canal	Santhal Parganas	1957	8.11	10,110
Badua Reservoir	Bhagalpur	1969	62.80	42,490
Kharagpur Lake	Monghyr	1959	2.40	2,630
Nagi Reservoir	,,	1959	4.01	2,050
Lower Kiul Project	,,	1959	8.67	25,900
Kaurihari	Monghyr	1960	5.65	11,650
Sakri Lower Valley—Stage I	Patna	1952	3.38	20,240
,, —Stage II	Gaya	1961	3.79	5,060
Panchane—Phase II	Patna	1963	4.41	12,000
Lower Morhar	Gaya	1962	5.68	14,970
Dhawa	,,	1961	1.55	4,250
Upper Morhar	,,	1961	5.61	14,570
Lilajan	,,	1958	6.50	22,660
Batane	,,	1959	1.85	6,710
(b) Projects under construction				
Chandan Reservoir	Bhagalpur	IV Plan (Probable)	99.20	40,150
Khudia Weir	Dhanbad	V Plan (Probable)	5.80	4,740
Udrasthan	Gaya/Patna	V Plan (Probable)	13.50	24,880
Morwe	Monghyr	IV Plan (Probable)	12.61	4,900
Paimar	Patna	IV Plan (Probable)	8.98	8,090
Baksha	Hazaribagh	IV Plan (Probable)	6.70	30,300
Total for Bihar			277.61	328,370

Table 8.9 – Contd.

1	2	3	4	5
West Bengal				
(a) Completed Projects				
(i) Pre-Plan Projects				
Eden Canal	Burdwan	1881	2.66	16,190
Midnapore Canal	Midnapore	1889	8.41	49,780
Damodar Canal	Burdwan	1935	12.41	72,850
(ii) Plan Projects				
Beria Canal	Bankura	1953	2.18	2,020
Suvankar Danra	,,	1958	1.71	2,430
(b) Projects under construction				
Damodar Valley Project	Dams located in Bihar Irrigation benefits in Burdwan, Bankura, Hooghly & Howrah	IV Plan (Probable)	*295.26 (*Irrigation portion)	365,000
Mayurakshi Project	Dam in Bihar—Benefits in Birbhum, Burdwan and Murshidabad.	IV Plan (Probable)	204.60	247,000
Kangsabati Project	Bankura, Midnapore & Hooghly	V Plan (Probable)	460.00	385,000
Soharajore	Purulia	1972 (Probable)	5.56	4,850
Hindglow	Birbhum	V Plan (Probable)	9.79	12,440
Bandhu	Purulia	IV Plan (Probable)	4.23	2,020
Total for West Bengal			1,006.81	1,159,580
Grand Total			1,284.42	1,487,950

8.47 All the major and medium projects so far undertaken would, on completion, provide irrigation facilities to an area of about 1.49 million hectares. The major contributors are the Damodar Valley Project (0.365 million hectares), the Mayurakshi Project (0.247 million hectares) and the Kangsabati Project (0.385 million hectares). Irrigation facilities so far created under all the projects are of the order of 0.94 million hectares.

8.48 In addition to the major and medium projects, there are the minor schemes which irrigate quite a large percentage of the total area irrigated in the region. The source-wise irrigation during 1967–68 was as given below:

Table 8.10

Source-wise Irrigation in the Basin

(Thousand hectares)

Source of irrigation	Area irrigated		Total	Percentage to total area irrigated
	Bihar	West Bengal		
1	2	3	4	5
Canals	191.2	576.9	768.1	41.0
Tanks	103.4	253.4	356.8	19.1
Wells (Tubewells included)	154.8	5.3	160.1	8.5
Other sources	469.6	117.3	586.9	31.4
Total	919.0	952.9	1871.9	100.0

8.49 The average delta at the canal head in major projects like the Damodar Project, the Mayurakshi Project and the Kangsabati Project works out to about 0.91 m. These projects contribute the major share of the total area to be irrigated under the projects so far undertaken and the delta adopted for these projects could safely be adopted for the other projects also without any appreciable degree of error. On this assumption, the total water diverted for irrigating 1.49 million hectares, which is expected to be brought under irrigation when all the projects so far undertaken are completed and fully developed, would be of the order of 13,568 m. cu. m.

8.50 In the absence of data regarding the delta obtainable, under minor irrigation schemes, the same delta of 0.91 m. as assumed for the major and medium projects has been adopted. The water requirements of 1.17 million hectares, which were irrigated by minor schemes during 1968-69 would be of the order of 10,702 m. cu. m.

Reservoir Losses

8.51 On the basis of assumptions detailed in para 1.33 the reservoir losses from the various schemes in the basin will be as under:

(i) Major and Medium Schemes	2,118 m. cu. m.
(ii) Minor Schemes (tanks)	3,530 m. cu. m.
Total	5,648 m. cu. m.

8.52 Thus, on completion and full development the total water utilised from all the major, medium and minor irrigation schemes under operation and under construction in 1968-69 would be of the order of 29,918 m. cu. m. (28,366 m. cu. m. surface+1,552 m. cu. m. of ground).

There are a number of major industries like the Steel Plants at Durgapur, Burnpur, Kulti and Bokaro, a fertiliser factory at Sindri, collieries at Jharia and Raniganj and other industries situated in the region, which require large quantities of water. On a rough estimate, the present requirement of water of all these industries is put at 1,233 m. cu. m. Thus, the total water utilisation, for all the projects committed so far, would be about 31,151 m. cu. m.

FUTURE DEVELOPMENT

8.53 The average water potential of the basin is of the order of 45,145 m. cu. m. (para 8.33). So far, about 31,151 m. cu. m. of water has been committed for irrigation projects and industrial uses (para 8.52) leaving 13,994 m. cu. m. of water for future development.

8.54 It is understood that the Bihar Government has in view a number of major and medium projects to be taken up in the future in the basin. The details are given in Table 8.11.

Table 8.11

Future Projects in the Basin

Sub-basin	Project	Area to be benefited in hectares
1	2	3
Ajay sub-basin	(1) Punasi Dam	22,257
	(2) Sarkunda Dam	25,657
	(3) Burhi Dam	26,709
	(4) Siktia Barrage	36,421
	(5) Pachva Dam	Investigations are yet to be done. No details are available.
	(6) Raghunathpur Dam	
	(7) Tetaria Tanr Dam	
	Total for Ajay sub-basin	111,044
Kiul sub-basin	(1) Nagi Nadi Dam	2,489
	(2) Nakti Reservoir	6,313
	(3) Barner Reservoir	26,709
	(4) Minor schemes	41,682
	Total for Kiul sub-basin	77,193 (approx)
Gumani sub-basin	Gumani Barrage	14,095
Bhena & Koa sub-basin	(1) Sugathan Reservoir	3,642
	(2) Bhorabandh Barrage	1,700
	(3) Minor schemes	8,701
	Total for Bhena & Koa sub-basins	14,043
	Grand Total or say	216,375 0.22 million hectares

8.55 The West Bengal Government has also proposed the Upper Kangsabati Project in the Kasai sub-basin to provide irrigation to 0.06 million hectares. Medium and minor schemes in West Bengal may also irrigate an equal area. Thus, the total area to be irrigated from future projects in West Bengal may be of the order of 0.12 million hectares.

8.56 The total area to be irrigated from the proposed future projects is of the order of 0.34 million hectares and will utilise about 3,633

m. cu. m. (with delta of 0.91 m. and reservoir losses at 20% of water diverted).

The rivers under consideration serve one of the very important industrial regions in the country and the water requirement of industries will have to be kept in view for further future water resources development.

FLOODS, WATERLOGGING AND DRAINAGE

8.57 Unlike the rivers of North Bihar, those in south Bihar do not have any flood problem. Some flooding takes place at their confluence points with the Ganga. This is of a short duration and not serious.

Of the rivers flowing from the Chottanagpur plateau into West Bengal, the Damodar used to be the worst affected due to floods. The river used to bring down large quantities of silt from the hill regions which were deposited in its bed in the plains resulting in the inundation of large areas, erosion of its banks and a shifting of its course. Earlier, some embankments had been constructed along the banks of the river, downstream of the Anderson Weir, as a measure of flood protection. With the construction of the Maithon, the Konar, the Tilaiya and the Panchet Hill dams during the Plan periods, the flood problem of the Damodar was more or less brought under control.

The other rivers which cause a certain amount of flooding in the West Bengal region are the Ajay, the Rupnarayan and the Kangsabati. Embankments have been constructed for a considerable length on these rivers to control floods.

It is reported that the districts of Midnapore, Howrah and Hooghly suffer from waterlogging. According to the estimates of the West Bengal State Government, in the Midnapore district alone an area of nearly 0.25 million hectares is annually subject to waterlogging. The State Government has undertaken a number of measures like excavation of drainage channels, desilting and re-sectioning of the existing drainage channels, and augmenting the capacity of drainage channels with the help of pumps to relieve the waterlogging problems in the affected areas.

The congestion of drainage in rivers like the Damodar, the Ajay and the Kangsabati in their lower reaches is quite considerable due to the flatter slopes. The silt brought down from the upper reaches gets deposited as the slopes are flattened and the capacity of the river channels get reduced. Also, whenever the main rivers are in flood, the flow in the tributaries backs up, causing the water to spill over the banks and to inundate the land.

SOIL CONSERVATION

8.58 The problem of soil erosion in the Damodar, the Mayurakshi and the Kasai sub-basins is serious. According to the surveys conducted, the observed rate of silting in the Maithon Dam is of the order of 7.38 m. cu. m. annually againt the designed rate of 0.84 m. cu. m. In the case of the Panchet Hill dam the rate of silting has been observed as 13.74 m. cu. m. annually against a designed rate of 2.44 m. cu. m.* In the case of the Mayurakshi reservoir, the observed rate of silting was 0.14 m. cu.m. against the assumed rate of 0.04 m. cu. m. per 100 sq. km. These figures indicate the necessity of soil conservation in the sub-basins where huge reservoirs have been constructed at enormous cost. It is imperative that intensified efforts should be made to reduce the soil erosion in the upper catchments of these sub-basins.

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*Sedimentation data of selected reservoirs in India (revised edition), Central Water and Power Commission, March, 1969 (Unpublished).

SALIENT FEATURES OF THE MAIN GANGA BASIN

(i) Source: In the Gangotri glacier in the Himalayas in the Uttar Kashi district of Uttar Pradesh. (Latitude 30°55′N, Longitude 79°5′E).

(ii) Length:	km.	miles
Uttar Pradesh	1,450	901
Common boundary between Uttar Pradesh & Bihar	110	68
Bihar	445	276
West Bengal	520	323
Total	2,525	1,568

(iii) Drainage area:	sq. km.	sq. miles
Uttar Pradesh	71,302	27,530
Bihar	9,182	3,545
West Bengal	26,847	10,365
Total	107,331	41,440

(iv) Population (1971 Census)	41.46 millions	
(v) Density of population	386 per sq. km.	1,000 per sq. mile
(vi) Average annual run-off of the basin	42,555 m.cu.m.	34.5 MAF.

	Thousand hectares	Thousand acres
(vii) Culturable area (1967-68)	6,878	16,996
(viii) Net area sown (1967-68)	5,937	14,071
(ix) Gross area sown (1967-68)	7,875	19,460
(x) Net irrigated area (1967-68)	1,914	4,730
(xi) Gross irrigated area (1967-68)	2,229	5,506
(xii) Ultimate irrigation by major and medium projects under operation and construction in 1968-69	1,370	3,384

		m.cu.m.	MAF
(xiii) Water utilisation, including reservoir losses on completion and full development from major, medium and minor projects under operation and construction in 1968-69	Surface water	11,643	9.44
	Ground water	6,604	5.35
	Total	18,247	14.79

CHAPTER IX

THE MAIN GANGA BASIN

The Basin

The basin extends over an area of 107,331 sq. km., and covers large areas in the States of Uttar Pradesh, Bihar and West Bengal. The State-wise distribution of the drainage basin is given below:

Uttar Pradesh	71,302 sq. km.
Bihar	9,182 „ „
West Bengal	26,847 „ „
Total	107,331 sq. km.

THE RIVER SYSTEM

9.2 The Ganga rises in the Gangotri glacier in the Himalayas at an elevation of about 7,010 m. above the mean sea level in the Uttar Kashi district of Uttar Pradesh. At its source the river is called the Bhagirathi. It descends down the valley up to Dev Prayag where it is joined by the Alaknanda, another hill stream rising from the twin glaciers the Bhagirath Kharak and the Satopanth. After its confluence with the Alaknanda, the combined stream is called the Ganga. The river continues to flow down in torrents and cascades along the valley for a distance of approximately 160 km. and after cutting through the Siwalik range of hills, it emerges into the Plains at Hardwar in Uttar Pradesh. Thereafter the flows in a series of channels separated from each other by islands. The main stream flows close to the left while the principal branch flows by the town of Hardwar on the right bank, joining the main stream at Kankhal about 4 km. below. The headworks of the Upper Ganga Canal, one of the most important irrigation works in Uttar Pradesh and providing irrigation to 0.7 million hectares is situated on this branch. The bed of the river is rocky up to 20 km. downstream of Hardwar. Usually the bank is high on one side and low on the other and the river is apt to change its course during the annual floods.

9.3 At Nagal in the Bijnor district, the Ganga takes a wide sweep towards the southwest, maintaining this direction for several kilometres. It continues in a southerly/south-easterly direction either forming the boundaries of or flowing through the Bijnor, Muzaffarnagar, Meerut, Moradabad, Bulandshahar and Budaun districts. During its course through the Meerut and Moradabad districts, the river flows in a wide bed constantly changing its course. The Narora Weir from where the Lower Ganga Canal takes off to irrigate 0.528 million hectares is constructed across the river in this reach. Continuing to flow south-eastwards, the river forms the boundary between the Etah and Budaun districts. The Ramganga, the first major tributary of the Ganga, joins it from the left in the Hardoi district.

9.4 Further lower down, the Ganga forms the boundary between the Kanpur and Unnao districts. In a wide and sandy bed the river changes its channel almost every year. At Allahabad the Ganga receives its biggest tributary, the Yamuna from the right.

9.5 Another right bank tributary, namely, the Tons, joins the Ganga about 30 km. below Allahabad. Varanasi is situated on the left bank of the Ganga about 150 km. downstream of Allahabad. The Gomati joins the Ganga immediately below Varanasi from the left.

9.6 After leaving Uttar Pradesh, the Ganga enters Bihar in the Shahabad district and immediately receives two important tributaries—the Ghaghara from the left at Chapra and the Son from the right near Arrah. The Gandak, yet another important left bank tributary, joins the Ganga near Patna. After its confluence with the Gandak, the Ganga forms the boundary of the Patna and Muzaffarpur districts for about 38 km. Opposite bank in the Patna district, the river touches the Monghyr district whereafter it flows in a south-easterly direction in a long reach of 50 km. The river, in its course through the Monghyr district, is wide and deep at all times of the year. At Pathar Ghat in the Saharsa district, the river receives the Kosi, an important left bank tributary. Apart from the Son, other important tributaries to join the Ganga on its right bank in Bihar are, the Pun-Pun, the Kiul, the Man, the Chandan and the Gerua.

9.7 After its confluence with the Kosi, the Ganga continues its eastward flow in Bihar for another 40 km. As it enters West Bengal, the river swings round the Rajmahal hill range opposite Manihari Ghat and starts flowing almost due south. The delta of the Ganga can be said to start from Farakka in West Bengal. The river divides into two arms about 40 km. below Farakka. The left arm called the Padma flows eastward into Bangladesh while the right arm of the river called the Bhagirathi continues to flow south in West Bengal. The Bhagirathi divides the Murshidabad district into two equal portions. South of this district, the Bhagirathi forms the whole eastern boundary of the Burdwan district except in a small reach where it enters the Nabadwip district. In this reach, it receives two right bank tributaries viz. the Dwarka and the Ajay.

9.8 The Bhagirathi receives the Jalangi just above Nabadwip town (an offshoot of the Padma taking off about 55 km. below the offtake point of the Bhagirathi. It is also called the Bhairab in its upper reaches). After its confluence with the Jalangi, the Bhagirathi known as the Hooghly forms the boundary of the Hooghly and the 24 Parganas districts. Calcutta, the biggest city in India is situated on the banks of the Hooghly. The Hooghly receives a left bank tributary viz. the Bagherkal upstream of Calcutta. Below Calcutta, the river first flows south and then nearly due west and south-west as far as Achipur. It then flows almost due south and receives the Damodar—on its right bank—opposite the Hooghly point. Immediately downstream it receives the Rupnarayan also on its right. These two tributaries have set up in the river the dreaded moving shoals, known as the James & Mary Islands, which make navigation in the Hooghly very difficult. After Diamond Harbour, the river resumes a southerly direction until it debouches into the Bay of Bengal. The mouth of the river at its junction with the sea is about 25 km. wide. Shortly before its outfall into the Bay of Bengal, the river divides into two arms on either side of Sagar Island. The channel on the left is called the Baratala river or channel creek (locally known as the Mayurganga). It is fed by several channels or creeks and ultimately joins the Bay of Bengal near Dhovlal. The right channel receives the Haldi river in the Midnapore district and it also ultimately debouches into the Bay of Bengal.

9.9 The left arm of the Main Ganga which flows into Bangladesh where it is called the Padma is joined by the Brahmaputra and the Meghna and all these rivers form a huge delta before ultimately falling into the Bay of Bengal. In the delta, the river divides and sub-divides into a number of channels all of which ultimately find their way into the sea.

9.10 The total length of the Ganga from its point of origin to the point where it falls into the sea is about 2,525 km. (measured along the Bhagirathi and the Hooghly) of which 1,450 km., lie in Uttar Pradesh, 445 km. in Bihar and 520 km. in West Bengal. The river forms the boundary between Uttar Pradesh and Bihar for over a length of 110 km.

CLIMATE

9.11 In the head reaches of the river, before the river comes out into the plains at Hardwar, the climate in the Ganga basin is influenced by the Himalayas. The winter is very cold whereas the summer is moderate. In the plains, however, the summer is very hot, with the maximum temperature rising up to 48°C. Winter temperatures in the plains fall as low as 1°C. In the lower most reach of the river in West Bengal, however, the climate is moderated by the presence of a large number of channels, beels and tanks.

9.12 The Ganga rising in the northern districts of Uttar Pradesh, flows from west to east practically through the whole of northern India. The rainfall though varying from region to region, is dominated by the south-west monsoon from June to September. As one advances towards the east, the period of the monsoon is extended over six months in a year i.e. from May to October. In Uttar Pradesh, the Dehradun district gets the highest rainfall (2,142 mm.) while the Aligarh district receives the lowest (663 mm.). The variation of rainfall in Bihar is not so pronounced as in Uttar Pradesh. The Santhal Paraganas district receives the highest rainfall (1,377 mm.) while the lowest rainfall is in the Monghyr district (992 mm). In West Bengal the Howrah district gets the highest precipitation (1,629 mm.) while the Nadia district gets the lowest (1,310 mm.).

9.13 There are one departmental and one agro-meteorological observatories of the India Meteorological Department with the basin.* The departmental observatory is located at Calcutta and the agro-meteorological observatory at Dehradun.

SOILS

9.14 The alluvial soils in the plains are very fertile and fit for cultivation of most crops. In the hill districts of Garhwal, Almora and Dehradun, the soils mostly comprise forest soils and hill soils. In the Bijnor and Saharanpur districts where the Ganga just emerges into the plains, red soil is found.**

LAND USE AND AGRICULTURAL PRACTICES

9.15 Land use details in the basin for the year 1967–68 are given in Table 9.1.

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*Evaporation Data (India), India Meteorological Department (April, 1970).

**Indian Crop Calendar, Ministry of Food, Agriculture, Community Development and Cooperation (1967).

Table 9.1

Land Use Details in the Basin

(Thousand hectares)

Item	State			Total
	Uttar Pradesh	Bihar	West Bengal	
Geographical area	7,130	818	2685	10,733
Reporting area	7,044	904	2681	10,629
Area under forests	1,442	77	434	1,953
Area not available for cultivation	1,165	151	482	1,798
Culturable area	4,437	676	1765	6,878
Uncultivated culturable area	721	126	94	941
Net area sown	3,715	550	1671	5,937
Area sown more than once	1,243	213	482	1,938
Total cropped area	4,959	763	2153	7,875
Net irrigated area	1,375	212	327	1,914
Gross irrigated area	1,631	266	332	2,229
Percentage of net area sown to culturable area	83.8	81.4	94.7	86.3
Percentage of net irrigated area to culturable area	31.0	31.4	18.5	27.8
Percentage of net irrigated area to net sown area	37.0	38.6	19.6	32.2

9.16 The upper part of the basin up to Hardwar and some area in the Varanasi district are hilly. The rest of the area lies in the plains. Out of a total reporting area of 10.63 million hectares nearly 1.96 million hectares (18.4%) is under forests and 6.88 million hectares (64.7%) is culturable. Of the culturable area nearly 86.3% is cultivated annually. A characteristic feature of agriculture in the basin is the high percentage (27.8%) of the cultivated area with irrigation facilities. Irrigation under canals constitutes nearly 44.5% while irrigation from ground water resources (wells and tubewells) covers nearly 44.8% of the total area irrigated.

9.17 Agriculture, whether under irrigated or unirrigated conditions, is dominated by food crops, as in other parts of India. Under irrigated conditions, paddy is the most important crop in Bihar and West Bengal while wheat and barley are the important crops in Uttar Pradesh. During 1967–68, in Bihar out of a total irrigated area of 0.266 million hectares, 0.177 million hectares (66.4%) were under paddy while in West Bengal, out of a total irrigated area of 0.332 million hectares, 0.281 million hectares (84.7% were under paddy. In Uttar Pradesh however, under irrigated conditions paddy was grown over only 0.153 million hectares (9.4%) while wheat and barley were grown over 0.801 million hectares (49.1% of total irrigated area). Other important irrigated crops in Uttar Pradesh were sugarcane (11.5%) and gram (5.3%). On the whole, rice and wheat are equally important crops grown under irrigated conditions in the basin. The details of the irrigated crops during 1967–68 are given below:

Table 9.2

Irrigated Crops in the Basin

(Thousand hectares)

Crop	State						Total for the basin	
	Uttar Pradesh		Bihar		West Bengal			
	Area	%age to total	Area	%age to total	Area	%age to total	Area	%age to total
1	2	3	4	5	6	7	8	9
Rice	153	9.4	176.7	66.4	281.2	84.7	610.9	27.4
Wheat	655.9	40.2	54.8	20.6	9.8	3.0	720.5	32.3
Barley	144.8	8.9	9.5	3.6	1.4	0.4	155.7	7.0
Gram	86.3	5.3	4.5	1.7	—	—	90.8	4.1
Sugarcane	188.4	11.5	3.1	1.2	6.1	1.8	197.6	8.9
Other food crops	275.3	16.9	16.1	6.0	33.1	10.0	324.5	14.5
Total food crops	1503.7	92.2	264.7	99.5	331.6	99.9	2100.0	94.2
Non-food crops	127.4	7.8	1.3	0.5	0.3	0.1	129.0	5.8
All crops	1631.1	100.0	266	1000.0	331.9	1000.0	2229.0	100.0

Crop Seasons

9.18 The main crop seasons are kharif and rabi. The kharif season starts with the onset of the south-east monsoon in June and ends by October. The rabi season lasts from November to March-April. In the West Bengal portion of the basin, rainfall starts in April-May and extends up to the end of October. Summer paddy is sown in January and February, making use of winter rainfall and is harvested in April-May. The autumn paddy (locally known as aman paddy) the important crop, is sown in

May-June and is harvested by the end of November or early in December. In the eastern portion of Bihar also, the same pattern prevails except that the crop is harvested in October or early in November.

REGIONAL ECONOMY

Population

9.19 On the basis of the 1971 Census* and on the percentage of the area of each district lying within the basin to the district as a whole, the total population in the Main Ganga basin would be about 41.46 millions of which 20.0 millions (48.2%) live in Uttar Pradesh, 4.0 millions (9.6%) in Bihar and the remaining 17.46 millions (42.2%) in West Bengal. The density of population works out to about 386 persons per sq. km. against 182 persons for India as a whole. Howrah district in West Bengal has the highest density of population with 1,625 people per sq. km., while the Tehri Garhwal district in Uttar Pradesh has the lowest with only 55 persons per sq. km.

9.20 There are two cities in Uttar Pradesh namely Kanpur and Varanasi having more than one lakh of people each. Allahabad city is situated at the confluence of the Yamuna and the Ganga. Another important town in Uttar Pradesh on the banks of the Ganga is Hardwar. In Bihar, there are two cities namely, Patna and Bhagalpur having more than one lakh each. In West Bengal, Howrah, Calcutta and their satelite towns like South Sub-urban, Dum Dum, Bally and Baranagar etc. each have population of more than one lakh.

As in other basins, in the Main Ganga basin also agriculture is the predominant occupation of the people. In the industrial pockets like Howrah, Calcutta in West Bengal, Allahabad, Kanpur and Hardwar in Uttar Pradesh and Patna district in Bihar, the percentage of people, in occupations other than agriculture is significant. Of the total population of 33.2 millions, 38.5 per cent constitute the working force. Of the working force, 71.6 per cent are cultivators and agricultural labourers while the remaining 28.4 per cent depend on tertiary and other services for their living.

Forests and Agriculture

9.21 Forests largely occupy the hilly region of Uttar Pradesh before the river emerges into the plains of Hardwar. In Uttar Pradesh, 20.5 per cent of the total drainage area is under forests. In Bihar it is 8.5 per cent and in West Bengal it is 16.2 per cent. The culturable area constitutes 64.7 per cent of the total area of the basin and 86.3 per cent of the culturable area is cultivated annually. A characteristic feature of cultivation in the basin is that nearly 27.8 per cent of the cultivated area has irrigation facilities. The major projects which have made this possible are the Upper and the Lower Ganga Canals.

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*Census Paper I of 1971 (Supplementary), Registrar-General (India).

Power

9.22 According to the surveys conducted by the Central Water and Power Commission, the hydro-power potential of the Main Ganga is of the order of 1592 MW at a 60 per cent load factor. Most of the sites for the generation of hydro-power are located in the hilly terrain of Uttar Pradesh and so far the generation of hydro-power in the Main Ganga has been negligible.

Absence of hydro-power in the basin has been partly made good by the generation of thermal power. A number of thermal power stations have been established in the basin. Details are as follows:

Table 9.3

Thermal Power Stations in the Basin

Name of the Thermal Power Station	Location	Installed Capacity
1	2	3
Pankhi Thermal Station	Kanpur (Uttar Pradesh)	284 MW
Barauni Thermal Station	Barauni (Bihar)	265 MW
Bandel Thermal Station	Near Calcutta	330 MW
	Total	879 MW

Mineral Wealth

9.23 Except for some limestone found in the Dehradun and Tehri Garhwal districts of Uttar Pradesh, the Main Ganga basin is devoid of minerals of any significance.*

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*Techno-Economic Survey of Uttar Pradesh, NCAER.

Industries

9.24 In Uttar Pradesh, the industries are concentrated in the cities of Kanpur, Allahabad and Varanasi. Cotton, jute and woollen textile mills are located at Kanpur. The Silk fabric industry is located at Varanasi. Light engineering industries are located at Allahabad and Varanasi. An antibiotics factory and a Heavy Electricals Factory have recently been established at Hardwar. A number of sugar mills are situated in various towns situated along the Ganga to make use of the large quantity of sugarcane grown in the area.

In Bihar, the most important industry situated on the banks of the Ganga is the oil refinery at Barauni. Other small industries and light engineering industries are situated at Patna and Bhagalpur.

In West Bengal, the most important agro-based industry in the basin is based on jute. A number of jute mills are situated in the Hooghly and Howrah districts. Calcutta, which is the most important city on the Ganga, has innumerable number of light and medium sized engineering industries. There are a good number of rice mills in the rice growing Hooghly and Howrah districts.

Communications

9.25 The basin has a good network of roads. National Highway No. 2 connecting Delhi to Calcutta via Varanasi passes through the basin. Other National Highways are NH 27 (Allahabad-Dewa), NH 29 (Ghazipur-Gorakhpur), NH 31 (Patna-Purnea), NH 6, 34, 35 (all connecting Calcutta to different parts of West Bengal and beyond).

The Northern and Eastern Railways serve the area. The broad gauge line from Delhi to Calcutta runs almost parallel to the river for most of its length.

The Ganga is navigable from Kanpur down to the sea. Small and medium sized craft ply on the river.*

WATER RESOURCES

Surface Water

9.26 The Ganga has been gauged for a long time at Hardwar and Narora from where the Upper and the Lower Ganga Canals respectively take off. A number of gauge and discharge sites have been established since 1958.

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*Navigable Waterways of India, Central Water and Power Commission (1961).

The Central Water and Power Commission, has estimated the average anual runoff of the Main Ganga (excluding all its tributaries) as 42,555 m. cu. m.*

Ground Water

9.27 The Geological Survey of India has conducted extensive and systematic surveys for ground water in the Gangetic plains of Uttar Pradesh, Bihar and West Bengal. The details are given in the following paragraphs.**

Hydrogeological studies in the Bijnor and Saharanpur districts have been carried out in the Bhabar-Tarai belt and the adjoining Gangetic alluvial plains. In the Bhabar-Tarai belt the groundwater occurs under confined conditions. Large scale grounwater development is possible in the Gangetic alluvium. Groundwater occurs both under unconfined and confined conditions in the Aligarh and Etah districts. In the Aligarh district near surface groundwater occurs within 10 m. of the land surface. In the Farrukhabad, Fatehpur and Rae Bareli districts the groundwater occurs both under water table and confined conditions. In the Kanpur and Varanasi districts near surface groundwater occurs under water table conditions.

The Jaunpur district is underlain by alluvial deposits of quaternary age and large scale development of groundwater development by means of tubewells is possible in most parts of the district. The area surveyed in the Mainpuri district is underlain by quarternary alluvium. In the Mirzapur district groundwater occurs both in the alluvium and in hard rock. In the hard rock, groundwater occurs as disconnected bodies. The alluvium in the Pratapgarh district comprises of various grades of sand, gravel, pebbles, clay and kankar and holds good possibility of groundwater. In the Unnao district groundwater occurs under water table conditions in the alluvium and there is scope for development. In the Allahabad district groundwater occurs under near surface conditions.

The Patna district is underlain by quarternary alluvial deposits comprising clay, sand and occasionally, gravel. Groundwater occurs under confined conditions and a large number of tubewells have been constructed for irrigation. Groundwater in the Monghyr and Bhagalpur districts occurs both in confined and water table conditions.

Surveys conducted so far in the Malda district indicate that the area has possibilities of ground water development by means of heavy duty tubewells. The whole of the districts of Murshidabad and Nadia and about 5,000 sq. km. of the 24 Parganas district have been covered by the studies. In addition, an exploratory project has been opened in the Calcutta metropolitan district. Groundwater occurs in a thick zone of saturation within the alluvium, under water table conditions. In the Hooghly district the water table rests at depths ranging from 1.5 m. to 5.0 m. below the land surface. Groundwater in the Howrah district occurs under confined conditions.

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*Report of the Technological possibilities of irrigation projects in India, Central Water and Power Commission (Unpublished).

**Ground Water Resources of India, Status and Surveys Prospects and Perspectives, Geological Survey of India (August, 1970).

The surveys mentioned above indicate the presence of extensive groundwater in the basin. A large number of tubewells have already been constructed to provide irrigation to large areas. However, a quantitative assessment of the groundwater resources of the basin is yet to be made.

EXISTING DEVELOPMENT

9.28 Prior to independence only two projects namely the Upper Ganga Canal and the Lower Ganga Canal were in existence in the basin. These are described in the following paragraphs:

Upper Ganga Canal

9.29 One of the most important irrigation works constructed in India in the pre-Plan period is the Upper Ganga Canal taking off from the Ganga at Hardwar, in Uttar Pradesh. The Project was conceived and constructed by Proby T. Cautley during the period 1840 to 1854. As first constructed, the project did not have any permanent arrangements to divert water into the canal. The natural channel (one of the branches of the Ganga) flowing near Hardwar town was made use of to divert practically the entire cold weather flow in the river by the construction of temporary obstructions across the other branches. The Upper Ganga Canal took off from this channel and provided irrigation in Saharanpur and other districts in Uttar Pradesh. This arrangement was in force for nearly fifty years. With the increase in the demand for water, the temporary arrangement described above was found to be totally inadequate and the State Government took up the construction of a permanent head works in 1913 and completed it in 1920. It consists of a weir about 550 m. long fitted with 1.8 m. high falling shutters and located about 3 km. upstream of the old regulator. The Upper Ganga Canal System comprises 910 km. of main canal and branches and 5,280 km. of distributaries and provides irrigation facilities in the Saharanpur, Muzaffarnagar, Meerut, Bulandshahr and Aligarh districts. The total area irrigated annually under the Upper Ganga Canal is nearly 0.7 million hectares.

Lower Ganga Canal

9.30 The Lower Ganga Canal takes off from the Narora Weir in the Bulandshahr district of Uttar Pradesh. The project was constructed in 1879. It consists of a weir across the Ganga at Narora and a main canal taking off on the right bank. The weir is 1,160 m. long and is fitted with falling shutters. The main canal is nearly 100 km. long and there are large number of branches and distributaries providing irrigation to an area of 0.528 million hectares annually in the Bulandshahr, Kanpur, Farrukhabad, Etawah and Etah districts.

9.31 The project which was intended to increase the capacity of the Upper Ganga Canal to 297 cumecs was completed during the Second Plan period to provide irrigation to an additional area of 0.036 million hectares in the Upper and the Lower Ganga Canal Systems.

9.32 The Ramganga Project, one of the most important projects to be undertaken by the Uttar Pradesh Government in the Ramganga basin provides for diversion of 142 cumecs into the Ganga through a feeder canal for increasing the intensity of irrigation in the Upper and the Lower Ganga Canal Systems.

9.33 In addition to the above projects, three pumped canal schemes namely Dalmau, Bhoupali and Zamania have been undertaken during the Third and Fourth Plan periods for augmenting irrigation supplies in the tail reaches of the Sarda and the Karamnasa systems in the Rae Bareili, Varanasi and Ghazipur districts. The total area to be irrigated from these three pumped schemes would be of the order of 0.111 million hectares. These three pumping schemes involve lifting a total quantity of 44 cumecs of water from the Ganga. The details of these schemes have been described in the respective sub-basins.

9.34 Another important project to be undertaken on the Ganga is the Farakka Barrage in the Murshidabad district of West Bengal. The project aims at the preservation of the port of Calcutta by inducting certain quantum of water into the Bhagirathi-Hooghly.

9.35 The existing projects namely the Upper and Lower Ganga Canals and the three pumped canal schemes, provide irrigation facilities to an area of 1.37 million hectares.

9.36 In addition to the above major and medium projects, there are a few tanks, many wells and tubewells providing irrigation to considerable area. The source-wise irrigation in the basin during the year 1967–68 was as given below:

Table 9.4

Source-Wise Irrigation in the Basin

(Thousand hectares)

Source of irrigation	Area irrigated			Total	Percentage to total area irrigated
	Uttar Pradesh	Bihar	West Bengal		
1	2	3	4	5	6
Canals	518.2	87.6	245.6	851.4	44.5
Tanks	28.5	14.9	43.8	87.2	4.5
Wells (Tubewells included)	804.5	52.6	0.6	857.7	44.8
Other sources	24.2	57.2	36.7	118.1	6.2
Total	1,375.4	212.3	326.7	1,914.4	100.0

9.37 Irrigation under wells and tubewells is extensively practised in the basin. Canal irrigation constitutes nearly 44.5 per cent of the total area irrigated, while wells and tubewells cover 44.8 per cent of the area.

9.38 According to the data available, the delta at the canal head obtained on the Upper Ganga Canal is 0.57 m. and that on the Lower Ganga Canal is 0.71 m. The average delta in the Sarda System (where the pumped canals mentioned in para 9.29 supply water) is 1.07 m. Taking into account the areas irrigated annually, the total water diverted for irrigation would be as follows:

(1) Upper Ganga Canal (including improvement works)	0.736 million hectares	4,194 m. cu. m.
(2) Lower Ganga Canal	0.528 million hectares	3,700 m. cu. m.
(3) Three Pumped Canals (Dalmau, Bhoupali and Zamania)	0.111 million hectares	1,233 m. cu. m.
	Total	9,127 m. cu. m.

9.39 No data regarding the delta obtained under the minor irrigation schemes is available. The average delta for major and medium schemes works out to 0.67 m. and adopting the same delta for minor schemes also, the water requirement for 1.22 million hectares which were irrigated under tanks and other sources during 1968–69 would be of the order of 8,185 m. cu. m.

Reservoir Losses

9.40 The major and medium projects so far executed in this basin are either diversion schemes or pumped canals and hence the question of reservoir losses under them does not arise. As regards minor schemes (tanks), the losses, on the basis of assumptions detailed in para 1.33, will be 935 m. cu. m.

9.41 Thus, the total water so far committed for irrigation under major, medium and minor schemes under operation and construction in 1968–69 would be of the order of 18,247 m. cu. m. (11,643 m. cu. m. of surface water and 6.604 m. cu. m. of groundwater).

9.42 There are a large number of industries in cities like Calcutta, Kanpur, Allahabad and Barauni which are situated on the banks of the Ganga and draw their water requirements from the river. No data is available regarding the quantity of water required by them. On a very rough estimate, the total requirement of industries may be put at 1,233 m. cu. m.

9.43 Another demand on the water of the Ganga is for the drinking water requirements of a large number of towns and cities situated on its banks and the water required under the Farakka Barrage Scheme. Data is not available regarding the exact quantity of water required to meet these demands. However, it is bound to be large and will have to be taken into account in the future development of water resources in the basin.

FUTURE DEVELOPMENT

9.44 Two new projects namely (i) the Tehri Dam and (ii) the Kotli Bhel Dam are contemplated across the Ganga to further increase areas irrigated under the Upper and Lower Ganga Canals. Besides increasing irrigation under the Upper and Lower Ganga Canals, each of these projects will also generate 600 MW of power.

9.45 The Tehri Dam, as proposed, will be situated on the Bhagirathi near the town of Tehri upstream of the Upper Ganga Canal headworks at Hardwar. It will be a rock fill dam about 237 m. in height having a gross storage capacity of 3,330 m. cu. m. 600 MW of power is expected to be generated. The tail water from the power house will help in increasing irrigation under the Upper and Lower Ganga Canals.

9.46 The Kotli Bhel Dam is expected to be 169 m. high. It will generate 600 MW of power and provide additional water in the existing Upper and Lower Ganga Canal Systems for increasing irrigation.

9.47 The above two projects are expected to increase irrigation to the extent of 1.2 million hectares under the Upper Ganga Canal and Lower Ganga Canal Systems. Adopting the average delta of 0.65 m. as obtained under the Upper and Lower Ganga Canal Systems, the future projects would divert about 7,586 m. cu. m. for irrigation. Assuming reservoir losses at 20 per cent of water diverted for irrigation, the total water utilised would be of the order of 9,103 m. cu. m.

FLOODS, WATERLOGGING AND DRAINAGE

9.48 The Ganga during its course in Uttar Pradesh has very few flood problems up to Allahabad. Below Allahabad, however, the river causes considerable damage due to spills during high floods. The river also erodes banks near Badrinath, Varanasi, Ballia, Mirzapur etc. The Uttar Pradesh Government has constructed the Ballia-Baria Bund on the Left Bank of the Ganga near the Ballia town to protect lands from floods.

In Bihar, the Ganga by itself does not cause major flood problems. However, when the river is at a high stage, the discharges from the tributaries get backed up and cause widespread damage in the sub-basin and also at their confluence points with the Ganga. The condition is worsened if the floods in the Ganga and its tributaries synchronise. Such a phenomenon is not infrequent. The Bihar Government, to alleviate the flood problems of the Ganga, has constructed the following three embankments in the State:

1.	Gupta Lakhmania Embankment	19 km.
2.	Gogri Narainpur Embankment	43 km.
3.	Khargola Embankment	43 km.

Differences of opinion have been expressed regarding the advisability of constructing embankments in the Ganga basin and fears have been expressed that embankments tend to increase the high flood level due to the silting up of channels. The High Level Committee on Floods in 1958 studied this problem and recommended that no further embankments beyond those already taken up in the Second Five Year Plan period should be undertaken without detailed flood routing studies.

The Bhagirathi-Hooghly (the name of the Ganga in the West Bengal Portion) was the main course of the Ganga until about 400 years back. Now, the Bhagirathi functions as a spill channel only and the Main Ganga flows along the Padma in Bangladesh. With the reduction of the discharge in the Bhagirathi, the channel capacity in that river has been deteriorating from year to year thus affecting the navigability of the river and the functioning of the Calcutta port. Due to reduced upland water supplies, the sea tides in its lower reach penetrate far up the river and bring in large quantities of silt which lead to a rise in the bed level of the river. The reduction of the upland supplies has also affected the natural flushing of the rivers in West Bengal and this has increased drainage congestion in many of the offshoots of the river.

SOIL CONSERVATION

9.49 The problem of soil erosion in the basin is particularly serious in the Himalayan tract covering parts of Dehradun, Chamoli, Pauri, Garhwal, Tehri Garhwal, Uttar Kashi and Almora districts. The soils in this region are very thin and all exposed slopes are susceptible to severe erosion and to gullying. Landslides are fairly common in the area. Lower down, in the plains the slope is gentle, except in the vicinity of natural drainages where steep slopes have been created through erosion spread over centuries. Destructive erosion first starts from the banks of natural drainage where the runoff has to negotiate steep slopes. The banks have been denuded of their vegetal cover and in almost all cases cultivation has been carried to the water line. The prevailing type of erosion is gullying and ravine formation.

Forests in Bihar and West Bengal occupy about 10 per cent and 16 per cent of the geographical areas respectively. The percentages are low when compared with the all India average and the standards laid down in the Forest Policy Resolution of the Government passed in 1952. Afforestation of the catchment is called for to reduce the erosion hazards.

For the conservation of river supplies it is important that soil conservation measures be taken up in the cultivated areas and in the culturable but not yet cultivated areas of the basin and in the areas under forests.

SALIENT FEATURES OF THE BRAHMAPUTRA BASIN

(i) Source: The Great glacier mass in the northern-most chain of the Himalayas, called Kubiganga (Kailash range), south of the lake called Konggya Tsho. (Latitude 30°31′N, Longitude 82°10′E).

	Km.	Miles
(ii) Length of the Brahmaputra river		
In Arunachal	218	133
In Assam	698	425
Total	916	558

	Sq. km.	Sq. miles
(iii) Drainage area:		
Arunachal	81,424	31,437
Nagaland	10,803	4,171
Assam	70,634	27,272
Meghalaya	11,667	4,505
West Bengal	12,585	4,859
Total	187,113	72,244

(iv) Population (1971 Census)	17.65 millions	
(v) Density of Population	94 per sq. km.	243 per sq. mile
(vi) Maximum discharge at Pandu in 1962	72,472 Cumecs	2,559,300 Cusecs
(vii) Minimum discharge at Pandu	N.A.	N.A.
(viii) Average annual runoff at Pandu (observed during 1956-62 & 1966-68)	499,914 m.cu.m.	405.29 MAF

	Thousand hectares	Thousand acres
(ix) Culturable area (1967-68)	12,146	30,014
(x) Net area sown (1967-68)	2,758	6,815
(xi) Gross area sown (1967-68)	3,275	8,093
(xii) Net area irrigated (1967-68)	691	1,708
(xiii) Gross area irrigated (1967-68)	697	1,722
(xiv) Area irrigated after completion and full development of Fourth Plan projects	1,061	2,622
(xv) Probable additional irrigation by future projects	N.A.	

(xvi) Water utilisation including reservoir losses:

		m.cu.m.	MAF
(a) On completion & full development of major, medium and minor projects under operation and construction in 1968-69	Surface water	6,058	4.91
	Ground water	220	0.18
	Total	6,278	5.09
(b) On completion & full development of Fourth Plan projects	Surface water	6,820	5.53
	Ground water	683	0.55
	Total	7,503	6.08

Note: All statistics pertain to the part of the basin lying in Indian territory only.
N.A.—Not available.

CHAPTER X

THE BRAHMAPUTRA BASIN

The Brahmaputra basin extends over an area of nearly 580,000 sq. km. It lies between east longitude 82°0′ and 97°50′, and north latitudes 25°10′ and 31°30′. The basin covers large areas in China (Tibet), India, Bhutan, Sikkim and Bangladesh. In India, the basin lies in the Union Territory of Arunachal i.e. NEFA and the States of Assam, Nagaland, Meghalaya and West Bengal. The State-wise distribution of the drainage basin within the country is given below:

Table 10.1

Drainage Area—Brahmaputra Basin

State/Union Territory		*Drainage area* (Sq. km.)
Arunachal (NEFA)		81,424
Assam		70,634
Nagaland		10,803
Meghalaya		11,667
West Bengal		12,585
	Total	187,113

The total area of the basin lying in India is equal to the area of the State of Gujarat.

10.2 The Bramaputra basin is bounded on the north by the Himalayas, on the east by the Patkai range of hills running along the Assam-Burma border, on the south by the Assam range of hills and on the west by the Himalayas and the ridge separating it from the Ganga Basin. The basin has a maximum east-west length of about 1,540 km. and a maximum north-south width of about 682 km. along 93° east longitude. The basin is of an irregular shape.

10.3 The upper portion of the basin lying in Tibet (China) comprises mostly mountain ranges and narrow valleys. Similar is the case with the portion of the basin lying in Arunachal and Nagaland. In Assam and Meghalaya the basin consists of hills, forests, tea gardens and a valley about 80 km. wide on the average. In West Bengal, also, the basin covers hills, forests, tea gardens of the State's northern districts besides the fertile plains in the districts of Cooch-Behar and West Dinajpur. In Bangladesh, the basin consists largely of fertile plains and delta areas.

THE RIVER SYSTEM

10.4 The Brahmaputra is one of the largest rivers in the world traversing a distance of about 2,900 km. through Tibet (China), India and Bangladesh and draining an area of nearly 580,000 sq. km.

10.5 It rises in the Great glacier in the northern-most chain of the Himalayas in the Kailas range at an elevation of about 5,150 m. at a latitude of 30°31′N, longitude of 82°10′E, just south of the lake called Konggyu Tsho. Many tributaries merge in the infant river from near the Mariam La pass, which separates its basin from the Manasarowar Lake, in which two other great rivers, the Indus and the Sutlej have their origin.

10.6 The river, under its Tibetan name of Tsangpo flows eastwards, through southern Tibet for about 1,700 km. keeping a course roughly parallel to the main range of the Himalaya and meets the first main tributary from the north, the Raga Tsangpo near Lhatse Dzong; the river Ngang Chu which flows by the large trade centre of Gyantse joins it from the south near Shigatse, the second town of Tibet. The river is then replenished by the waters of the Kyichu from the north. The latter is an important tributary, on which stands the sacred town of Lhasa, the capital of Tibet.

From Lhatse Dzong, the Tsangpo has a wide navigable channel for about 640 km. downstream. It is one of the most remarkable navigable waterways of the world with boats sailing at an altitude of 3,650 m. and more above mean sea level.

At Tselha Dzong, the river is joined from the north by the Griamda Chu. Beyond Pe (altitude 3,000 m.) the river abruptly turns to the north-east and north and flows in a succession of rapids between the high mountains of Gyala Pari and Namcha Barwa (7,756 m.) and turns to the south and south-west to emerge from the foothills under the name, first of Siang and then of Dihang. It enters India across the Sadiya frontiers tract, west of Sadiya town into the Assam valley. Here it is joined by two more tributaries viz. the Dibang and the Luhit. From here onwards the river is known as the Brahmaputra.

10.7 The river then rolls down the Assam valley from east to west for a distance of about 720 km. with its channels meandering from side to side and forming many islands. One of these islands, Majuli covers an area of 1,250 sq. km. During its course the river receives many more tributaries both from the north and the south. Some of them are trans-Himalayan rivers with considerable discharges. In the north the principal tributaries are the Subansiri, the Kameng, the Dhansiri, the Manas, the Champamati, the Saralbhanga and the Sankosh. On the south bank, the main tributaries are the Noa Dihing, the Buri Dihing, the Disang, the Dikhu and the Kopili. The Brahmaputra also has some important tributaries flowing through North Bengal. They are the Tista, the Jaldhaka, the Torsa, the Kaljani and the Raidok. Emerging swiftly from narrow gorges with steep slopes, these rivers widen out considerably in the plains.

Swinging round the spurs of the Garo hills, near Goalpara, the river enters Bangladesh and flows for a distance of about 270 km. across the alluvial plains of that country before joining the Ganga at Goalundo. The united streams of the Brahmaputra and the Ganga flow under the name of Padma. About 105 km. below Goalundo, the main stream is joined on the left bank by another large river, the Meghna, which has its source in high mountains in Assam. From the confluence southward, the river now known as Meghna, makes a very broad estuary before its entry into the Bay of Bengal.

10.8 The principal tributaries of the river as mentioned in para 10.7 above have widely divergent characteristics. The charcteristics of the north bank tributaries are:

(i) They have very steep slopes and shallow braided channels for a considerable distance from the foothills and in some cases, right up to the outfall.

(ii) They have coarse sandy beds and carry a heavy silt charge.

(iii) They generally have flashy floods.

10.9 The characteristics of the south bank tributaries on the other hand are:

(i) They have comparatively flatter grades and deep meandering channels, almost from the foothills.

(ii) The beds and banks are composed of fine alluvial soils.

(iii) They have a comparatively low silt charge.

10.10 The North Bengal tributaries bring enormous quantities of silt, and have shallow and wide aggrading beds. They erode their banks and not infrequently change their course.

10.11 The more important tributaries of the Brahmaputra, lying in Indian territory, are described in the following paragraphs.

10.12 *The Subansiri* rises in the mountains of Tibet, the birthplace of many mighty rivers. Near its source, several mountain torrents, or rather, a big 'Chu' family of streams, drain into the main valley. The principal stream belonging to this 'Chu' group is the Sikung Chu which may be considered as the main source of the Subansiri. The Sikung Chu soon changes its name to Nye or Niye Chu and flows past the Karutra Temple after its confluence with the Char Chu. A few kilometres lower down, the Yume Chu merges with the main stream. About 40 km. further downstream, it receives the Tsari Chu and the combined waters assume the name of Subansiri. After travelling from its main source for a distance of about 225 km. it then traverses another 48 km. to enter the Miri Hills. After piercing the Miri Hills, the river flows through a narrow gorge. About 48 km. downstream from the entry to these Hills, it is joined by an important mountain tributary, the Kamala. The river then runs for another 32 km. to emerge from the hills through a short canyon in to the plains. Leaving the hills near Dulungmukh, the river flows through the fertile plains of the North Lakhimpur Civil Sub-division. After flowing about 97 km. from the hills, it meets the Kherkutia-Suti, a spill channel of the Brahmaputra and changes its name to Lohit. The length of the river in the plains from Dulungmukh to its outfall in the Brahmaputra is about 153 km. The total length of the Subansiri is about 442 km. out of which 192 km. lie in NEFA and 190 km. in Assam. The river drains an area of 32,640 sq. km.

10.13 *The Bhorelli* (or Jia-Bhorelli or Kameng) rises from the unsurveyed hills of the Himalayas presumably in the territory of Tibet beyond the Aka and Dafla Hills. After flowing for more than 193 km. in the hills within Indian territory, mainly through the Kameng district of Arunachal, it enters the plains near Bhalukpung. Very little is known about this river in its upstream reaches as the valley is covered with dense vegetation and impenetrable forest. Although numerous small streams join the river, it is small in size and capacity up to its confluence with the main tributary, the Bichom, 56 km. upstream of Bhalukpung. After its confluence with the Bichom, the river flows through a narrow gorge up to

Bhalukpung and is not joined by any tributary worth the name. Leaving the hills near Bhalukpung, the river first flows east between two ranges of low hills and then turning sharply to the south, follows a tortuous course to the Brahmaputra, which it joins about 11 km. east of Tezpur town. Downstream of Bhalukpung, the principal tributaries are the Upper Dikrai, the Khari Dikrai, and the Bor Dikrai on the left bank and the upper and the Lower Sonai on the right bank. The total length of the river is 264 km. out of which 198 km. lie in Arunachal and 66 km. in Assam. The catchment area of the river is 11,843 sq. km.

10.14 *The Manas* is formed by the confluence of the Tongsa (Mangde) and the Kur, which rise from the Great Himalaya Ranges near the village of Sufali, a few kilometres inside Bhutan. From Sufali, the river Manas flows in a north-south direction for about 8 km. and enters the Kamrup district of Assam near 26°47'N, 90°57'E. After flowing in a generally south-westerly direction for about 29 km. the river enters the Goalpara district. From the village of Agrong it follows a serpentine course for about 75 km. and outfalls into the Brahmaputra near Jogighopa. Enroute it is met by the river Ai, which rises in the Black Mountains at an altitude of about 4,915 m. near the village of Bhangbarai at 27°15'N, 90°23'E. From its source, the Ai flows for about 80 km. in a generally north-south direction and then 30 km. in a south-easterly direction till its outfall into the right bank of the Manas. The total length of the Manas via its longest tributary, the Kur, is 376 km. out of which about 104 km. lie in India. Its total catchment area is about 37,500 sq. km.

10.15 *The Buri Dihing* is formed by the confluence of the Namphuk and the Namchik, which rise from the Patkai ranges and the Maganton river which is the southern branch of the Noa Dihing. The Namphuk, which may be considered the principal source of the Buri Dihing, originates in the Yapawp Bum ranges at 96°42'E, 27°22'N, at an altitude of 2,300 m. and flows in a westerly direction through hills covered with dense semi-tropical forest for a distance of 116 km. till it meets the Numchik river. The combined flow travels for 16 km. before it meets the Maganton river, a southern branch of the Noa Dihing river when it assumes the name of Buri Dihing. The Namchik river also has its source in the Patkai Bum range 95°48'E, 27°1'N at an altlitude of 2,264 m. and flows in the north-easterly direction through hills covered with dense forest, for a distance of 64 km. when it meets the Namphuk river. The combined flow of the Numphuk-Namchik and the Maganton flows south-west in a serpentine course for 40 km. before meeting the major tributary Tirap near Ledo, the centre of the coal mining area of Assam. The Tirap has its origin at 95°42'E, 27°0'N in the northern slopes of the Patkai range at an altitude of 2,780 m. It flows towards the north-east through gorges for about 113 km. and then turns west and meanders along its course in the plains for about 24 km. joining the main river, the Buri Dihing near Ledo. The Tirap is one of the main tributaries of the Buri Dihing, from its southern bank. From its confluence with the Tirap, the river Buri Dihing moves towards the south and emerges from the hills near Margherita flowing through the fertile and prosperous plains of the Lakhimpur district. Several streams meet the Buri Dihing during its journey through the plains of Lakhimpur, the most important of which are the Digboi, the Tipling, the Tingrai, the Sesa on its right bank and the Dirak, the Namsang, the Disam on its left bank. Its course has sharp curves and loops till it reaches the Brahmaputra, 32 km. downstream of Dibrugarh town. The total length of the river Buri Dihing is 362 km. including the Namphuk river, which is considered to be its source. Its catchment area up to the confluence with the Brahmaputra is 8,473 sq. km.

10.16 *The Dhansiri* (*South*) rises in the south-west corner of Nagaland below the Laishiang peak. For the first 37 km. from the source, the river flows in a north-westerly direction, whereafter, turning to the north-east it flows for about 76 km. up to Dimapur. Beyond Dimapur, the direction of flows is generally northerly up to Golaghat, where the river takes an abrupt turn and flows west, ultimately to join the Brahmaputra, near Dhansirimukh, opposite Majuli island in the Brahmaputra river. Although numerous small streams join the river, it is small in size and capacity up to its confluence with the main tributary, the Diyung, which is about 154 km. downstream of Dimapur. From its source up to Dimapur, the Dhansiri forms the boundary between the districts of Cachar, Nowgong and Nagaland Beyond Dimapur, the river enters the Sibsagar district of Assam and flows throughout in that district, up to its confluence with the Brahmaputra. The main tributaries of the river on the right bank are the Diyung, the Diphu, the Bhogdoi or the Golabil and those on the left are the Nambar, the Doigrung and the Kalyani. Besides these tributaries, there are several sub-tributaries also and among them the Kakadanga, the Rengma and the Bhagti are worth mention. The total length of the river from its source up to its confluence with the Brahmaputra at Dhansirimukh is approximately 354 km. The Dhansiri drains an area of about 12,250 sq. km.

10.17 *The Kopili* rises near Malangpa village in the Mikir and North Cachar Hills district of Assam State at an elevation of about 900 m. at north latitude 25°12′ and east longitude 92°45′ and flows in a generally north to north-westerly direction for about 60 km. along the border of the Khasi and Jaintia Hills district of Meghalaya, and the Mikir and north

Cachar Hills district of Assam. Thereafter, about 9 km. west of Lohang village, it takes a turn and flows in a generally north-easterly direction for about 60 km. to a point where it is met by a major tributary the Diyung, on its right bank about 13 km. west of Lungding village. Thereafter, the river flows in a generally north-westerly direction for about 19 km. in the Mikir and North Cachar Hills district and thereafter for about 43 km. it forms the boundary between the Nowgong and Mikir and North Cachar Hills district. Flowing for about another 5 km. in the same direction in the Nowgong district, it receives on its right bank another major tributary, the Jamuna near the town of Jamunamukh Flowing in a westerly direction for about 40 km., it receives the Borpani from the left, opposite Chaparmukh. Its direction is now completely to the west and after about 23 km., the Umium joins it on the left bank about 5 km. west of Dharamtul. After flowing about 2.5 km. the river crosses the Gauhati-Tezpur railway line and about 4 km. further down it outfalls into the Kalang on its left bank, which ultimately joins the Brahmaputra near Raja Mayang from the left after flowing for another 37 km. Its total length is 256 km., of which 78 km. form the common border of Meghalaya and Assam and the remaining 178 km. lie in Assam. The river drains a total area of 15,800 sq. km. The Diyung, the Jamuna from the right and Borpani and the Umium from the left are its important tributaries.

10.18 *The Tista* is the largest of the rivers of North Bengal. It rises in the Himalayas in North Sikkim. Running through narrow gorges for nearly 138 km., it debouches into the plains of the Jalpaiguri district at Sivok. Up to this point, its course is southerly and thereafter south-easterly. It flows in a steady course up to Jalpaiguri town beyond which it records frequent changes. It has a number of tributaries, many of which are mountain torrents. The more important of these are the Rangni, the Rangpo, the Great Ranjit, the Reli, the Lish, the Gish and the Chel. Draining an area of 12,540 sq. km. of which only 3,017 sq. km. lie in North Bengal, it joins the Brahmaputra near Rangpur town in Bangladesh after traversing a length of 309 km.

10.19 *The Jaldhaka,* like the Tista, also has its origin in Sikkim. It traverses a total distance of 186 km., passing through Bhutan, the Darjeeling, Jalpaiguri and Cooch-Behar districts of West Bengal, and Bangladesh, till it finally falls into the Brahmaputra near Alipur in the Rangpur district. It has a catchment area of 3,958 sq. km. up to the Indo-Bangladesh boundary, a small portion lying in Sikkim and Bhutan. The Murti and the Diana are its main tributaries.

10.20 *The Torsa* takes its birth in the Chumbi valley of Tibet where it is called the Machu. Its length of run in the Tibetan territory is nearly 113 km. It travels through Bhutan for a length of 145 km. where it is known as the Amochu, before entering the Jalpaiguri district of West Bengal above Totapara. Its course, which in Bhutan is in narrow and deep gorges, widens out as it enters the plains of the Jalpaiguri district. The river travels for a distance of nearly 100 km. through North Bengal, and after flowing past Balarampur, it joins the Brahmaputra after being met by the Raidok and the Sankosh rivers. Its main tributaries in the Jalpaiguri district are, the Holong, the Ghargharia and the Kaljani. Of the 4,883 sq. km. of catchment area of the Torsa, 2,737 sq. km. lie in Tibet and Bhutan.

CLIMATE

10.21 During the year, four distinct seasons occur in the Indian portion of the basin. They are (i) winter, (ii) summer, (iii) monsoon and (iv) autumn or post-monsoon.

10.22 The winter season begins in December and continues to the end of February. Light north-easterly winds blow down the Brahmaputra valley in Assam and light northerly to north-westerly winds in West Bengal. The weather is occasionally changed by the passage of western disturbances across the region; light rainfall occurs in January and February along the hills, increasing towards North-east Assam. Thunderstorms are rare in December and January and occur only on one or two days in February; these may occasionally be accompanied by a dust-storm or hail.

10.23 From March onwards, the hot weather starts and continues up to the last week of May. In this season the basin is under the sway of three air streams—a deep north-westerly current from Uttar Pradesh and Bihar, a shallow southerly stream from the head of the Bay of Bengal over the Orissa and Bengal coasts, and a shallower current of north-easterly to easterly winds from the Brahmaputra valley blowing over the plains of North Bengal and Bihar. With the interactions between these air streams, this is a season when marked instability develops in the atmosphere and severe thunderstorms occur extensively, sometimes preceded by dust-raising squalls. Rainfall increases both in amount and frequency as the season advances, being generally associated with afternoon or evening thunderstorms and squalls. They are generally more concentrated in Upper Assam. Hailstorms occur on one to three days in the season, especially in the Assam hills.

10.24 The monsoon sets in by the last week of May or in early June, being usually ushered in by a depression in the Bay of Bengal. Subsequently, a series of such depressions, forming at the head of the Bay and moving inland, give spells of continuous and moderate to heavy rain generally over the region. The monsoon withdraws in the last week of September or the first week of October. July and August are the rainiest months. Rain is most frequent and heavy on the southern slopes of the Khasi hills in the north-east corner of Assam, and in Northern Bengal. Much of the rainfall in June and September is associated with thunder-clouds, while thundery weather is less frequent in July and August.

After the withdrawal of the monsoon winds, light unsteady winds are experienced by the middle of October. Occasionally, in October, cyclonic storms from the Bay cross the Bengal coast bringing clouds and rain with them. Almost all the rain in this season is associated with thunder.

Rainfall

10.25 There are 208 reporting rain-gauge stations in the basin. The density works out to one station for every 2,413 sq. km. The number of gauges is, therefore, still insufficient, especially in the trans-Himalayan Brahmaputra. The establishing of more rain-gauges to obtain a balanced distribution over the entire basin is suggested. In selecting the locations for new rain-gauges, care should be taken that all areas in the basin are suitably represented.

10.26 The rainfall data of all the existing rain-gauge stations are being observed and printed by the Rainfall Registration Authorities of the concerned States. These data appear in the annual volumes of the Daily Rainfall of India compiled and issued by the India Meteorological Department. Such volumes are available since 1891.

10.27 During the post-winter months, the north-east monsoon finds its way into the Brahmaputra valley through a saddle in the high Himalayas, at their eastern end. The Assam range of hills gradually rise in height eastward from 300 m. in the Garo hills to about 3,000 m. in the Naga hills. The low clouds brought in by the south-west monsoon get interrupted on the southern face of the Khasi and Jaintia hills by a 1,830 m. high ridge and cause extremely heavy rainfall along the Cherrapunji-Mawphlang-Pynursla belt. This is generally of the order of 11,000 mm. per annum, the highest in the world. The clouds that pass over this 1,830 m. ridge along this belt, precipitate in the Brahmaputra valley, their intensity increasing towards the foothills of the Himalayas. The rainfall in the Brahmaputra valley ranges from 2,125 mm. in Kamrup to about 4,142 mm. in Tirap Division of the Arunachal. The Lanka area in Nowgong district on the north of the Khasi and Jaintia hills lies in the rain shadow region and in consequence, the annual rainfall there is only about 1,100 mm. The rainfall in the Tista valley varies from 1,635 mm. in West Dinajpur district to 3,945 mm. in Jalpaiguri district. During the monsoon months of May to October, about 85% of the precipitation in the basin occurs. About 12% of the annual rainfall occurs in March and April.

Temperature

10.28 During the winter season in January, the mean temperature over the catchment varies from 15.0°C to 17.5°C. The higher elevations in the Himalayan ranges experience lower temperatures.

During the summer season in April, the mean temperature in the lower part of the catchment varies from 25.0°C to 27.5°C. The temperatures are below 25°C in the upper parts of the basin notably in Arunachal.

In the rainy season, in the month of July, the mean temperature varies from 27.5°C to 30.0°C.

Towards the end of the monsoon season, in the month of October, the mean temperature over the basin varies from 25.0°C to 27.5°C. The Arunachal region experiences temperatures lower than 25.0°C.

10.29 Annual normals of temperature and relative humidity at some selected places located within the basin are shown in Table 10.2.*

Evaporation

10.30 Very little data on evaporation is available for the Brahmaputra basin. The India Meteorological Department has compiled the evaporation data in respect of 30 departmental observatories and 42 agro-meteorological observatories scattered all over the country having data for more than five years. Observations at all these places are taken with the standard U.S. Evaporation Pan (Class A) covered with wire-mesh. For the departmental observatories, the data pertains to the period 1959 to 1968 and is available month-wise, whereas the data for the agro-meteorological observatories pertains to the period 1961 to 1968 and has been presented for 12 periods into which the calendar year is divided for agro-meteorological purposes. Three departmental observatories are located in the Brahmaputra basin, one each at Dibrugarh, Gauhati and Shillong.

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*Indian Crop Calendar, Directorate of Economics and Statistics, Ministry of Food, Agriculture, C. D. and Cooperation (1967).

In addition, two agro-meteorological observatories are located at Tocklai and Titabar.*

Table 10.2

Temperature and Humidity Data—Brahmaputra Basin

Station	Annual normals of temperature		Annual normal of relative humidity (%)
	Maximum (°C)	Minimum (°C)	
1	2	3	4
Cherrapunji	20.5	14.2	73
Dibrugarh	27.3	18.5	85
Gauhati	29.3	19.2	81
Shillong	21.1	11.9	69
Sibsagar	27.5	18.8	87
Tezpur	28.7	19.5	82
Darjeeling	15.7	9.8	74
Jalpaiguri	29.2	19.1	82

SOILS

10.31 No systematic soil survey of the Brahmaputra basin has been carried out so far.

The basin covers fully all the five districts of Arunachal viz., Kameng, Subansiri, Siang, Luhit and Tirap, the Mokokchung district of Nagaland, the Lakhimpur, Sibsagar, Darrang, Nowgong, Kamrup and Goalpara districts of Assam and the Cooch-Behar and Jalpaiguri districts of West Bengal. Parts of Tuensang and Kohima districts of Nagaland, the North Cachar and Mikir hills district of Assam, the Garo hills, Khasi and Jaintia hills districts of Meghalaya, the Darjeeling and West Dinajpur districts of

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*Evaporation Data (India), India Meteorological Department (April, 1970).

West Bengal also lie in the basin. The principal soil types found in the various districts in the basin are shown below:*

Table 10.3

Soils of Brahmaputra Basin

Name of the State/U.T./District	Type of soils
1	2
Arunachal	
Kameng	Red loam.
Subansiri	Red loam, brown hill (on sand stones and shales), alluvial.
Siang	Red loam, brown hill (on sand stones & shales).
Lohit	Red loam, alluvial.
Tirap	Red loam, laterite.
Nagaland	
Mokokchung	Red loam, loams to fairly heavy clay, laterite
Tuensang	Red loam, loams to fairly heavy clay.
Kohima	Red loam, loams to fairly heavy clay.
Assam	
Goalpara	New alluvium, sands to loams.
Kamrup	New alluvium, sandy to clay loams.
Darrang	New alluvium, sands to clay loams.
Nowgong	New alluvium, clayey or sandy loams, laterite.
North Cachar and Mikir Hills	New alluvium (medium), red loam, laterite.
Lakhimpur	New alluvium (medium)
Sibsagar	New alluvium
Meghalaya	
Garo Hills	Laterite, new alluvium, heavy clay.
Jaintia and Khasi Hills	Laterite, new alluvium, loamy silt and fine silt.
West Bengal	
Cooch-Behar	Alluvium, sand, light loam, black loam.
Jalpaiguri	Terai (alluvium of sandy loam), hard black clay, deep brown light loam.
Darjeeling	Terai (alluvium of sandy loam), boulders, kankar, red soil.
West Dinajpur	Red to reddish black, old alluvium, clayey to stiff clayey, kankar.

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*Soils of India by S. P. Raychaudhari, R. R. Aggarwal, N. R. Datta Biswas, S. P. Gupta and P. K. Thomas.

LAND USE AND AGRICULTURAL PRACTICES

10.32 State-wise land use details in the basin, as in 1967–68, the latest year for which the statistics are available, are given below:

Table 10.4

Land Use Details—Brahmaputra Basin

(Thousand hectares)

Item	Name of the State					Total
	Arunachal	Assam	Meghalaya	Nagaland	West Bengal	
1	2	3	4	5	6	7
Gross Area	8,142	7,064	1,167	1,080	1,258	18,711
Area under forest	5	1,814	100	172	246	2,237
Area not available for cultivation	1	2,364	983	680	200	4,228
Culturable area	8,136	2,886	84	228	812	12,146
Uncultivated culturable area	8,136	965	—	197	90	9,388
Net area sown	N.A.	1,921	84	31	722	2,758
Area sown more than once	N.A.	364	10	1	142	517
Total cropped area	N.A.	2,285	94	32	864	3,275
Net area irrigated	—	566	21.5	5.8	97.8	691.1
Gross area irrigated	—	566	24.8	5.8	100.8	697.4
Percentage of net area sown to culturable area	—	66.56	100.00	13.60	88.86	22.68
Percentage of net area irrigated to culturable area	—	19.61	25.60	2.54	12.10	5.69
Percentage of net area irrigated to net area sown	—	29.46	25.60	18.71	13.62	25.09

The culturable area in the basin is about 5.62% of the total culturable area of the country. The total cropped area in the basin is about 2.09% of the cropped area in the country.

The area under irrigated crops is about 21.3% of the cropped area in the basin.

10.33 The general cropping pattern, State-wise is described as follows:

Assam

Of the gross irrigated area of nearly 566,000 hectares, 94.15% is under rice and the balance of 5.85% accounts for non-food crops, such as tea, oilseeds and jute.

Meghalaya

The entire irrigated area of about 24,800 hectares is under rice.

Nagaland

The entire irrigated area of about 5,800 hectares in this State is also under rice.

Arunachal

Crop-wise statistics are not available.

West Bengal

Of the irrigated area of about 100,800 hectares, about 79.37% is under rice and 3.37% under maize. Other irrigated crops are wheat, barley and sugarcane. Tea is an important non-food crop. Food and non-food crops cover about 87% and 13% of the irrigated cropped area respectively.

Summing up, of the total irrigated area in the basin, 92.26% is under rice and 1.11% under food crops, such as maize, wheat, barley and sugarcane. The remaining 6.63% is under miscellaneous non-food crops like tea, oilseeds and jute.

10.34 In Assam, the autumn rice is sown from mid-February to April and harvested during the period from June to August. The winter variety of rice is sown during the period from May to July and harvested during the period from November to January. The sowing period for jute is February-March and the harvesting period July-August. Castorseed is sown during June-July and harvested during November-December. The sowing period for sesamum is September-October while the harvesting period is December-January.

10.35 In West Bengal, the cultivation of paddy is carried out both by broadcasting as well as by transplanting. The sowing period for broadcasting autumn rice is March-June and for winter rice April-June. The corresponding harvesting periods are July-November and November-

December. The sowing period for transplanted autumn rice is May-June, winter rice June-August and summer rice October-February respectively. The corresponding harvesting periods are July-November, November-December and April-May. Maize is the only other important crop which is sown during April-June and harvested during July-August.

REGIONAL ECONOMY

Population

10.36 On the basis of the 1971 census* and the percentages of the area of each district within the basin to the district as a whole, the total population in the basin is about 17.65 millions. The State-wise distribution is shown below:

Table 10.5

Population Data—Brahmaputra Basin

State/Union Territory	Population (Millions)
1	2
Arunachal (NEFA)	0.44
Nagaland	0.33
Assam	12.87
Meghalaya	0.52
West Bengal	3.99
Total	17.65

10.37 The only city which has a population of more than one lakh is Gauhati. The average density of population in the basin is 94 persons per sq. km. The density varies from region to region within the basin. The most densely populated district of Cooch-Behar has 423 persons per sq. km. while the district of Mikir and North Cachar Hills with 30 persons per sq. km. is at the other extreme. 91.1% of the population in the basin live in rural areas and the balance 8.9% live in cities and towns. The working force constitutes about 29.1% of the population. Nearly 40.1% of the working force is engaged as cultivators, 20.7% as agricultural labourers and the balance of 39.2% is employed on other activities.

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*Census Paper I of 1971 (Supplementary), Registrar-General (India).

Forests and Agriculture

10.38 Forests and agriculture are the mainstay of the people. Nearly 11.96% of the total area of the basin is covered with forests. The forests are of many varieties, such as tropical deciduous, coniferous pine and bamboo. The area annually cropped in the basin is about 3.271 million hectares. Agriculture is generally rain-fed, except for about 0.697 million hectares of irrigated area, which mainly grows rice.

Power

10.39 The Central Water and Power Commission has conducted surveys to assess the hydroelectric potential of the country and has worked out the hydroelectric potential of the Brahmaputra basin as 13,426 MW at a 60% load factor which is about one fourth of the country's total hydroelectric potential. At present, the demand for the electrification of towns and industries etc. is being met by means of diesel and thermal power plants, besides three hydro-power stations at Umtru in Assam and Darjeeling and Kurseong in West Bengal.

Mineral Wealth

10.40 The principal minerals found in the basin are:*

Petroleum which occurs in the tertiary beds of Assam near Burma. Digboi remained the only source up to 1953-54 after which fields were discovered in the Naharkatiya, Hugrijan, Moran, Lakwa, Rudrasagar and Galiki regions of Upper Assam at a depth of more than 2,743 metres.

Coal—The main coal fields are found in the Garo, Jaintia and Khasi Hills in Meghalaya, Nazira-Borjan in Nagaland, Namchik (Tirap Division) of Arunachal (NEFA), Longloi area of Mikir Hills and Makum in Assam. Coal in small deposits is also found in the Darjeeling district of West Bengal.

Limestone is found in the Garo, Khasi, Jaintia and Mikir Hills.

Sillimanite—Practically the whole of India's sillimanite supply comes from Assam. It is used for making refractory bricks and certain types of ceramic ware. It occurs in the north-western portion of the Khasi Hills.

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*Techno-Economic Surveys of NEFA, Nagaland and West Bengal, NCAER.

Dolomite occurs in the north-east of the Jalpaiguri district of West Bengal in the high peaks of Duars ranges. The area covered is about 13 sq. km., mostly inaccessible, but the reserves are inexhaustible.

Copper is found in disseminated grains in slates and schists in the Darjeeling district of West Bengal. The ore has, however, a low copper content.

In addition to the above, many other minerals are being explored for by the Geological Survey of India in various regions of the basin notably Arunachal (NEFA) and Nagaland but their economic exploitation is not yet in sight.

Industries

10.41 The important industries in the basin are: Jute and petroleum products at Gauhati; petroleum and its bye-products at Digboi; plywood and hard and soft board at Darjeeling, Cooch-Behar, Gauhati and Dibrugarh; paper and cardboard and newsprint at Gauhati and Shillong; matches at Siliguri, Dhubri and Gauhati; glass and ceramics at Dibrugarh; fertilizers at Dibrugarh; and drugs and pharmaceuticals at Darjeeling, Gauhati, Nowgong and Shillong.

Communications

10.42 The basin is served by the North-East Frontier Railway with headquarters at Pandu near Gauhati. Some of the important routes are: the Siliguri-Alipur Duar-Fakirgram-Rangia-Pandu-Gauhati line, the Rangia-Tezpur-North Lakhimpur line, the Pandu-Silghat line, the Pandu-Lumding-Silchar-Lolaghat and Kalkatighat line, the Lumding-Neamati line, and the Lumding-Dibrugarh Town-Dangori and Likhapani lines.

The main National Highway runs from west to east, connecting Buxirhat to Cooch-Behar (West Bengal) via Jogighopa-Goalpara with Saikhowaghat (in Arunachal). There are two other National Highways, one connecting Gauhati and Tamabil (on the Khasi Hills, Bangladesh border) via Shillong, and the other branching out from the west-east National Highway connecting Dimapur and Kohima in Nagaland with Imphal in Manipur and Moreh on the Burma border. Many other roads have been constructed and improved, especially in the hill districts. Because of the riverine character of the land, ferries still present serious bottle-necks in the free movement of goods and persons by road.

10.43 The Brahmaputra used to be navigable up to Dibrugarh and even beyond, a distance of over 1,100 km. from the sea. Owing to the deterioration of the river channel, however navigation is now only up to Desang Mukh, 65 km. downstream of Dibrugarh. Important inland ports on the Brahmaputra in Assam are Dibrugarh, Neamati, Tezpur, Gauhati, Pandu and Dhubri. The bulk of traffic which used to be handled by Dibrugarh now moves through Desangmukh and Neamati.

The Subansiri, an important tributary of the Brahmaputra, is the feeder river for the north Lakhimpur area and is navigable by country boats throughout the year for about 143 km. from Subansirimukh to Chauldhawa ghat.* Some of the other important tributaries of the Brahmaputra that are navigable throughout the year by country boats are the Manas for a distance of 48 km. from the railway line to its confluence with the Brahmaputra; the Bhorelli from Buragaon Bagicha to its confluence with the Brahmaputra, a distance of 64 km.; the Dhansiri (South), for a distance of 48 km. from Golaghat town to Dhansirimukh; and the Kopili from Khariakhana to Jagigaon (confluence with the Kalong) a distance of 103 km. The Buri Dihing is navigable by country boats from Nawsang Tea Estate to Dihingmukh, a distance of 161 km. during the rainy season only. Small dugouts, however, play throughout the year.

In general, the plain or valley portion of the Brahmaputra basin is better served with communications in comparison with the hill areas which lack communications.

The economy of the basin largely depends on agriculture. With abundant rainfall and fertile valleys suitable for the cultivation of a wide variety of crops, the basin's potential for the development and diversification of agriculture is very great, and yet the progress of agriculture in the first three plans has not kept pace with the growth of population. The principal factor responsible for making agriculture unstable is the occurrence of floods.

WATER RESOURCES

Surface Water

10.44 The surface water potential of the Brahmaputra river system had been assessed at different times by different authorities. The first assessment was made in 1949, in the course of a basin-wise assessment of the water resources of the country which was carried out on the basis of Khosla's empirical formula. The annual run-off of the Brahmaputra basin had been assessed as 382,107 m. cu. m.†

In 1960, when irrigation potential studies were made by the Central

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*Navigable waterways of India, Central Water and Power Commission (1961).

†An appraisal of water resources by Dr. A. N. Khosla, UNESCO.

Water and Power Commission, the total annual runoff of the Brahmaputra and Barak basins together, was assessed as 590,714 m. cu. m.*

10.45 The work of the systematic observation of discharges on the Brahmaputra and its tributaries was taken up by the Central Water and Power Commission in the State of Assam in the year 1954 and continued till 1963.

After February 1963, the work of making discharge observations was handed over by the Central Water and Power Commission to the State Government, who have since then carried on the collection of hydrological data of all the major tributaries of the river. According to the observations pertaining to the years 1956–62 and 1966–68 the average annual runoff of the Brahmaputra at Pandu is 499,914 m. cu. m. The Assam State Government has mentioned the figure of 487,225 m. cu. m. in their preliminary memorandum to the Irrigation Commission.

The collection of hydrological data for the rivers Tista and Torsa which are important tributaries of the Brahmaputra was initiated by the then State Government in 1946 and has been carried on by the Government of West Bengal systematically since 1954.

10.46 The details of the existing gauge and discharge sites on the various rivers in the Brahmaputra basin are given in Table 10.6.**

Under the programme for establishing and maintaining Centrally sponsored key hydrological stations in the country, the Central Water & Power Commission have proposed the inclusion of the gauge and discharge sites on the Brahmaputra at Disangmukh and on the Jaldhaka at Kinhata. They have also included some of the existing sites in the programme.

Ground Water†

10.47 In Assam, so far, an area of nearly 17,000 sq. km. occupying parts of the Darrang, Kamrup, Goalpara and Lakhimpur districts in the northern portion of the valley has been covered by systematic ground water studies by the Geological Survey of India.

10.48 In the Darrang district, the northern-most piedmont zone, analogous to the 'Bhabar' belt of the Ganga Valley and occurring close to the foothills, is followed to the south by a narrow 'Terai' belt which merges

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*Report of the technological possibilities of irrigation projects in India, Central Water and Power Commission (unpublished).

**Replies of Assam and West Bengal to the questionnaire issued by the Irrigation Commission.

†Ground Water Resources of India, Status and Surveys, Prospects and Perspectives, Geological Survey of India (August, 1970).

Table 10.6

Gauge and Discharge Sites—Brahmaputra Basin

Name of Station	Name of River	Observations made for
1	2	3
Assam		
U/S of Pandu	Brahmaputra	Gauge & discharge
U/S of Bhimparaghat	Subansiri	-do-
U/S of N.T. Road Crossing	Ranganadi	-do-
U/S of N.T. Road Crossing	Dikrong	-do-
U/S of Silonipamghat N.T. Road Crossing	Jia-Bhorelli	-do-
U/S of N.T. Road Crossing	Puthimari	-do-
U/S of N.T. Road Crossing	Pagladiya	-do-
U/S of Chowki	-do-	-do-
U/S of Mathanguri	Manas	-do-
U/S of Rly. Bridge	Buri-Aie	-do-
U/S of Rly. Bridge	Champamati	-do-
U/S of Kokrajhar Rly. Bridge	Gaurang	-do-
U/S of Khowang	Buri-Dehing	-do-
U/S of A.T. Road Crossing	Jhanji	-do-
U/S of A.T. Road Crossing	Bhogdoi	-do-
U/S of A.T. Road Crossing	Dhansiri(s)	-do-
U/S of Bakuliaghat	Jamuna	-do-
U/S of Dobaka	Jamuna	-do-
U/S of Dharamtul	Kopili	-do-
U/S of A.T. Road Crossing	Dudhnoi	-do-
U/S of A.T. Road Crossing	Krishnai	-do-
U/S of Rongsai	Jinjiram	-do-
West Bengal		
Tista Bazar	Tista	-do-
Ghugamari	Torsa	-do-

imperceptibly into the alluvial flats close to the Brahmaputra river. The piedmont terraces are highly permeable in nature and ground water occurs generally at a depth of more than 30 m. below ground level. The water level in a number of permeable beds in the Terai belt lies 2 to 25 m. below ground level. The few borehole records indicate that a considerable thickness of aquifer material occur within 100 to 150 m. below ground level. In the alluvial flats, the water-level varies from one metre near the spring zone to 12 m. below ground level near Archaean inliers.

10.49 In the Goalpara district, the area drained by the Brahmaputra and its tributaries is geologically divided into two units viz. (i) unconsolidated recent Alluvium and (ii) Ferruginous older Alluvium. In recent alluvium, the water-table is at a depth of 3 to 6 m. below ground level while in older alluvium it varies from 12 to 20 m. below ground level.

10.50 In the Kamrup and Lakhimpur districts the basin is underlain by recent alluvium. The water-table occurs at a depth of 2 to 4 m. below ground level. In the Kamrup district, the water level in shallow tubewells down to a depth of 95 m. varies from 0.52 to 3.50 m. below ground level. An artesian belt, about 30 km. in length and 2 to 5 km. in width located in the 'Terai' has been demarcated, which extends from near the western boundary of the Darrang district to a point adjoining the Kamrup district. Tubewells in this belt tap aquifers occurring 50 m. below ground level, which are separated from the near-surface aquifers by a thick clay bed 20 to 34 m. below ground level.

10.51 Based on the data collected from existing tubewells in the gardens and defence establishments at Tezpur and various other places in the northern part of the valley, it can be safely assumed that the large-scale development of heavy duty tubewells (with an yield of 100,000 l.p.h. at a drawdown of 4 to 6 m.) is economically feasible throughout the valley from Lakhimpur to Goalpara on the north bank, between the Terai-Bhabar zone in the north and the river in the south, particularly in areas undelain by recent flood-plain deposits of recent alluvium.

10.52 On the south bank of the Brahmaputra river, no systematic geohydrological studies have been carried out so far. In this part the narrow alluvial tract is bounded on the south and south-east by Archaean crystalline rocks and Tertiary folded ranges, and occasionally cut across by rocky promontories as in the south Goalpara and Kamrup districts. However, short term investigations in Nowgang, Jorhat, Sibsagar and United Mikir and North Cachar hills have indicated the possibility of the existence of at least 90–120 metres of alluvial material including 15 to 30 m. of granular zones, quite near impervious boundary condition. The reported yields in tubewells vary from 15 to 40,000 l.p.h. at a drawndown of 5 to 8 metres, though the well-construction methods may not be fully dependable. It is expected that the groundwater potential will be better, away from the rocky boundaries and nearer the river channel.

10.53 The chemical quality of water, both from near-surface and deeper aquifer zones, is generally good and suitable for irrigation and for domestic purposes. However, at many places in the basin, an excess of dissolved iron to the extent of 4 ppm. and above, in the near-surface aquifers has been recorded.

10.54 In West Bengal, the major part of the Darjeeling district is characterised by very rugged topography and underlain by ancient crystalline metamorphites of Archaean age and other consolidated sedimentary rocks of the Himalayas. Here surface runoff is very high, groundwater is also quickly drained off and storage is negligible. In the foothills, where the piedmont type of deposits occur, the texture of the unconsolidated sediments are known to vary within short distances.

10.55 An area of about 3,400 sq. km. has been surveyed in the districts of Jalpaiguri and Cooch-Behar. The area forms the westernmost part of the Brahmaputra basin drained by the tributary systems of the Tista, Jaldhaka, Torsa etc. The area is underlain by alluvial sediments consisting of clay, silt, and sand varying in texture from coarse to fine, and gravel. Groundwater occurs under both water-table and confined conditions in the near surface and deep aquifers respectively. Depth-to-water varies from 2.5 to 6 m. below ground level during the pre-monsoon period. A copious discharge is expected from suitably designed large-diameter tubewells sunk to a depth of 160 m. in alluvium containing an adequate thickness of saturated granular material. Discharges of 3,100 to 2,400 litres per minute have been recorded for drawdowns of 3 to 11 m. In the northern parts of the districts the deposits are of the piedmont type and are represented by assorted materials ranging from very fine sands to pebbles and even boulders. The assorted nature of the granular materials somewhat restricts the large-scale development of groundwater. In some tea estates, 60 m. deep wells have been constructed with moderate yields of 60 to 80 kilolitres per hour for a drawdown ranging from 3 to 5 m. Chemically, except for a high concentration of dissolved iron in some localised pockets, the water has been found to be suitable for all types of use.

EXISTING DEVELOPMENT

10.56 The first Indian Irrigation Commission had not recommended any specific projects, to be taken up for construction in the Brahmaputra basin.*

10.57 Prior to Independence, no major or medium irrigation works worth the name existed in the entire Brahmaputra basin. In Assam, no major or medium irrigation project was taken up even during the First and the Second Plans. It was only in the latter part of the Third Plan that the following medium irrigation projects were undertaken:

(1) Jamuna
(2) Sukla
(3) Patradisha
(4) Longa

These projects are described in the following paragraphs.

Jamuna Project

10.58 The Project provides for the construction of a weir 354 m. long across the Jamuna river near Bakuliaghat in the Mikir hills. The area benefited will be in the Mikir hills and the Nowgong districts. Work on the project started in 1964 and was completed in 1969. The cost of the project is Rs. 39.6 million and the gross area which will be benefited will be 34,060 hectares, the net area being 25,600 hectares. During 1969, the entire area of 25,600 hectares was irrigated in the kharif season.

Sukla Project

10.59 The project envisages the construction of a weir across the Sukla river near Naokota. On completion, the project will provide irrigation to 32,640 hectares in the Kamrup district. The work on the project started in 1965 and is expected to be completed in 1971. The cost of the project is estimated at Rs. 29.8 million.

Patradisha Project

10.60 The Project costing Rs. 3.36 million has been taken up for providing irrigation in the tribal areas of the Mikir hills. The project consists of a weir across the Patradisha river, a tributary of the Jamuna, and a canal system to irrigate 2,430 hectares—1,620 hectares in kharif and 810 hectares in rabi. Work on the project started in 1965 and was completed in 1969. 1,620 hectares were irrigated during the kharif season of 1969.

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*Report of the Indian Irrigation Commission (1901-03).

Longa Project

10.61 The Project envisages the construction of a weir across the Longa river in Goalpara district. The project costing Rs. 6 million, will provide irrigation to 4,860 hectares. The work on the project is yet to be started.

10.62 In addition to the above, the Assam Government have also undertaken the Harguti irrigation scheme to irrigate annually 4,430 hectares—2,590 hectares during kharif and 1,840 hectares in rabi in the Hill districts. The scheme consists of a barrage across the river Harguti and a left bank canal system. Work on the scheme estimated to cost Rs. 4.28 million, started in 1968–69 and is expected to be completed during the Fourth Plan period.

The development of irrigation in the four districts of West Bengal forming part of the Brahmaputra basin has been rather slow. Only one medium project, namely the Karatowa project was taken up in 1957 at a cost of Rs. 4.64 million to benefit an area of 8,820 hectares in the Jalpaiguri district. The area irrigated by the project up to the end of March, 1969, was 3,157 hectares. The project was completed in 1969.

10.63 The particulars of the various projects under operation and construction in the basin are given in Appendices 10.1 and 10.2 respectively.

10.64 In the Brahmaputra basin the development of irrigation so far has been mostly through minor irrigation works such as small diversion works near the foothills to feed irrigation channels, lift irrigation schemes from rivers and streams in the hill region, tanks, and a few wells and tubewells. The diversion works usually comprise small boulder bunds across the rivers and irrigation channels locally called 'Dongs'. Sometimes the bunds across the streams are of earth or of a composite section made of earth and brush wood. These works were necessarily temporary in nature as the channels were quickly eroded and went out of use. The bunds were also washed away by the rising waters of the streams. The details of the net area irrigated by various sources like canals, tanks, wells etc., during the year 1964–65, State-wise, in the basin are given in Table 10.7.

10.65 The medium projects under operation and construction in the basin, on completion and full development, will use 458 m. cu. m. of

Table 10.7

Source-wise Irrigation—Brahmaputra Basin

(Thousand hectares)

Source of irrigation	State/U.T.					Total
	Arunachal	Assam	Nagaland	Megha-laya	West Bengal	
1	2	3	4	5	6	7
Canals	—	360.8	—	—	70.9	431.7
Tanks	—	—	—	—	2.3	2.3
Tubewells	—	—	—	—	9.8	9.8
Other sources	—	205.2	5.8	21.5	14.8	247.3
Total	—	566.0	5.8	21.5	97.8	691.1

waters. Since these are run-of-the-river schemes, no reservoir losses have been added.

In the absence of any statistics for minor schemes, the utilisation by such schemes has been estimated by the Commission on the basis of the total area irrigated under these sources. The approximate utilisation by minor projects including tank losses, at the beginning of the Fourth Plan works out to 5,820 m. cu. m.

The total utilisation by medium and minor projects undertaken up to the beginning of the Fourth Plan, on their completion and full development is of the order of 6,278 m. cu. m. (6,058 m. cu. m. of surface waters and 220 m. cu. m. of ground waters).

The requirements of industry in the basin are not readily available. However, in future, the requirements are expected to grow. The problem of water pollution in the basin through industrial wastes has not been reported so far.

FUTURE DEVELOPMENT

10.66 No new major or medium project is proposed to be taken up for construction in the basin in the Fourth Five Year Plan period.

By the end of the Fourth Plan, the area under minor schemes is expected to increase by about 173,360 hectares requiring nearly 1,225 m. cu. m. of water, including reservoir losses.

10.67 Thus, with the additional utilisation by the Fourth Plan minor projects, about 7,503 m. cu. m. of waters (6,820 m. cu. m. of surface waters plus 683 m. cu. m. of ground waters) would have been used for irrigating a total area of 1,061,479 hectares.

10.68 The Assam Government has indicated one major, five medium and thirty-seven minor schemes including lift irrigation projects, under investigation in the basin to be taken up in the future. West Bengal contemplates taking up one major and one medium project in the future in the basin. The details of the larger of these projects are given below:

Table 10.8

Future Projects—Brahmaputra Basin

Name of the project	Zone/ District	Source of supply (Name of river)	Ultimate irrigation (hectares)
1	2	3	4
Dhansiri Irrigation Project	Darrang (Assam)	Dhansiri	46,059
Sirajuli Irrigation Scheme	-do-	N.A.	3,840
Ninal Irrigation Project	-do-	N.A.	N.A.
Phulaguri Irrigation Project	-do-	N.A.	N.A.
Puthimari Irrigation Project	-do-	N.A.	N.A.
Panchnai Irrigation Scheme	-do-	Panchnai	N.A.
Tista Barrage Scheme	Darjeeling, Jalpaiguri, Cooch-Behar & West Dinajpur	Tista	546,330
Jarda Irrigation Scheme	Jalpaiguri	Jarda	4,925

Tista Barrage Scheme

10.69 The scheme envisages the construction of a barrage across the river Tista to divert the snow-fed Tista waters into the river Mahananda. This diverted water as well as the flow of the river Mahananda itself will be tapped at several points by the construction of three barrages across it. An area of 546,330 hectares is proposed to be irrigated in kharif, about 300,000 hectares in rabi and about 370,000 hectares during pre-monsoon months. Thus, this project is expected to ensure double cropping to about 450,000 hectares in West Bengal and 100,000 hectares in Bihar. The estimated cost of the project is Rs. 800 million, of which West Bengal's share would be Rs. 640 million.

Appendix 10.3 shows the details of the new schemes proposed by the various State Governments in the Brahmaputra basin.

FLOODS, WATERLOGGING & DRAINAGE

10.70 Under the influence of the south-west monsoon, the Brahmaputra basin is subject to severe and recurrent floods. In Assam, the riverine areas in the Brahmaputra and the Barak valleys comprise only 27% of the total area of the State, the remaining 73% of its area being covered by hills.* This adverse topographical feature, coupled with a heavy annual rainfall, ranging from 2,480 mm. in some places in the Brahmaputra Valley to 6,350 mm. or more in the North-Eastern Hills, and largely concentrated during the four to five monsoon months, is responsible for frequent and damaging floods. The total width of the Brahmaputra valley between the foothills is only 80 to 90 km., of which the river itself covers a width of 6 km. to 10 km. in most places; forests cover a few kilometres mostly along the foothills. Tea gardens in certain districts occupy much of the high land, and the remaining width of the valley, occupied by villages and cultivated fields, is very narrow. Assam is also subject to severe and frequent earthquakes which cause numerous landslides in the hills and upset the regime of the rivers. After the great earthquake of 1950, the bed of the Brahmaputra rose by about 3 m. at Dibrugarh in about 10 years and to varying extents in the other reaches also. This has naturally intensified the flood problem of the State.

19.71 A study of past floods shows that there is no regularity in the cycle of floods. Due to the causes just mentioned, floods during the last decade have been heavier than in the preceding decades. The years 1931, 1935, 1948, 1949, 1954 and 1962 had been years of high flood in the Brahmaputra valley. The maximum discharge of the Brahmaputra at Dhubri at the western boundary of Assam is considered to be of the order of 73,624 cumecs. The maximum discharge actually observed at Pandu was 72,472 cumecs in 1962. Along the main river there has been disastrous erosion near a number of towns. The town of Sadiya at the confluence of the Dibang and the Luhit disappeared in 1953. The erosion at Dibrugarh in 1954 was very severe and endangered the town. A major part of the town of Palasbari disappeared that year. There has been erosion at a number of other towns on the river bank, for instance at Dhubri, Bilasipara, Goalpara, Tarabari, etc. When the river is in full flood, it can carry away as much as 30 m. wide strip of land in a single day and almost 1.6 km. of width of the bank can disappear in a season.

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*Report of the Ministers Committee on Flood Control, Ministry of Irrigation and Power (1964).

10.72 The districts of Jalpaiguri, Cooch-Behar and Siliguri subdivision of Darjeeling in the northern region of West Bengal suffer frequently from floods in the Himalayan tributaries of the Brahmaputra such as the Tista, the Torsa, the Jaldhaka etc. These rivers flow through the Himalayan slopes and carry large quantities of debris and coarse sediment. They are also subject to flash floods. Whenever floods occur, due to the large quantity of sediment being deposited on the river bed in the flatter reaches, the channels are incapable of carrying the flood discharges and in consequence the rivers spill over on both banks causing flooding in the area. These rivers sometimes erode their banks and change their courses, abruptly opening out new channels with considerable damage to the neighbouring areas. According to the records very heavy floods occurred in north Bengal during the years 1877, 1886, 1892, 1895, 1900, 1902, 1905, 1906, 1926, 1948, 1950, 1952 and 1954. The latest flood havoc in this region was in 1968 when nearly 1,500 sq. km. of cultivated area was very badly affected, 1,975 human lives were lost and houses worth Rs. 92 million were damaged.

The year-wise flood damage in the Brahmaputra basin for the period 1953 to 1962 is given below:*

Year	*Damage in Rs. million*
1953	28.20
1954	265.70
1955	59.10
1956	116.30
1957	10.70
1958	80.00
1959	518.90
1960	81.50
1961	1.00
1962	243.40
Total	1,404.80

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*Flood Atlas of India—Central Water and Power Commission.

10.73 Since 1954 when the countrywide programme of flood control measures was initiated, many flood control works have been undertaken in the vulnerable areas. These include the construction of embankments, river training and town protection work, the raising of villages and drainage improvements etc. The progress made in the Brahmaputra basin to end of March 1969 is given below:

(i) Embankments (km.)	3,341
(ii) Town protection works (Nos.)	42
(iii) Drainage channels (km.)	700
(iv) Area benefited ('000 hectares)	111
(v) Expenditure incurred (Rs. million)	333

10.74 In order to ensure a reasonable degree of protection to the people from the recurring damage by floods in the Brahmaputra, it is necessary to implement an integrated plan for flood control, erosion control and drainage congestion relief in the State. To achieve this end it has been decided by the Assam Government in consultation with the Government of India to set up a three tier organisation comprising (i) the Brahmaputra Flood Control Board, (ii) the Brahmaputra Flood Control Commission and (iii) a Board of Technical Consultants. The Government of India has already set up the Brahmaputra Flood Control Board. The Board is a high-powered policy-making body and decides priorities in the implementation of the various flood control schemes. The Board also accords sanction to estimates and approves the allocation of funds. For preparing a comprehensive plan of the flood control of the valley and for execution of works, the Assam Government has set up the Brahmaputra Flood Control Commission. The Commission is a whole-time organisation and works within the broad framework of policy directions issued by the Brahmaputra Flood Control Board. The Government of Assam has also constituted a Board of Consultants to review the work of the Commission and advise on the complicated problems which might arise during planning, designing and construction.

10.75 The draft Master Plan for flood control for Assam has been prepared. The measures suggested would benefit a substantial additional area of about 0.757 million hectares at a cost of Rs. 600 million (1964 price level). The proposals for a long term solution of the flood problem as outlined in the draft Master Plan are summarised on page 226. The Master Plan is under revision and the total cost may be higher than Rs. 600 million. A major portion of this cost pertains to the Brahmaputra basin.

	Rs. million
(i) New embankments	97
(ii) Raising and strengthening of existing embankments	46
(iii) New drains	23
(iv) Sluices in embankments	21
(v) Town protection and anti-sea erosion works	87
(vi) Multipurpose reservoir and flood detention basins	275
(vii) Other works	49
(viii) Total estimated cost	598
	Say Rs. 600 million

To prevent the periodical recurrence of flood devastation in areas in north Bengal, the State Government has drawn up Master Plans for the control of floods in a number of rivers in that area. These schemes include the construction of flood embankments, soil conservation, afforestation and river drainage. The rivers covered and the costs are given below:

(i) Master Plan for the Tista river	Rs. 1,140 million
(ii) Master Plan for the Jaldhaka river	Rs. 94 million
(iii) Master Plan for the Raidak river	Rs. 310 million
(iv) Master Plan for the Torsa river	Rs. 283 million
Total	Rs. 1,827 million

The schemes have been phased over a period of 10 years due to a paucity of funds. It has been suggested by the State Government that the responsibility for flood control in northern Bengal should be taken over by the Central Government.

10.76 A 20-member team of Geologists of the Geological Survey of India has just completed the first phase of work in connection with the high-priority multi-disciplined geological studies of the Brahmaputra basin, at the instance of the Brahmaputra Flood Control Board. The Brahmaputra project is the first of its kind. Specialists in River Sedimentation, Ground Water and Engineering Geology, Geophysics and Geomorphology are studying the problem from their respective angles. Modern methods of Photo-geological interpretation are being used extensively. The studies are expected to yield basic data on the history and behaviour of the Brahmaputra and its tributaries which bring disaster every year to thousands in Assam and West Bengal. The recent field work has brought out several interesting aspects of the behaviour of the Manas, the Jia Bhoreli and the Subansiri rivers. Systematic geohydrological studies have been carried out in these sub-basins to assess the contribution of ground water to the flood problem. The data will also help in the sinking of tubewells for domestic water supply and for irrigation. Data regarding the artesian conditions prevailing in parts of the north bank has been collected. Engineering Geologists have surveyed dam sites in the Arunachal (NEFA) area to study their feasibility. The specialists are now analysing the data and carrying out laboratory studies. In view of the high priority given to this problem, the Geological Survey of India expects to finalise the report of the first phase of studies by mid-1972.

Waterlogging & Drainage

10.77 Waterlogging and drainage do not pose any problem in the irrigated areas of the districts covered by the Brahmaputra basin. However, the problem of drainage congestion during the flood season is frequently experienced in the plains of the portion of the basin lying in Assam.

When the Brahmaputra is in high flood, it also backs up its tributaries and makes them spill near their outfall. This phenomenon is prevalent in the case of practically all the tributaries. Apart from this backing up effect, the tributaries themselves, in most cases spill their banks during high flood in their own basins. As in the case of the Brahmaputra, all the tributary channels have also raised their banks and the ground slopes away from the banks, forming a subsidiary valley between two tributaries. This subsidiary valley drains the local rainfall between the two rivers and the flood spill from the rivers on either side.* The country is generally low between two adjacent tributaries and has a slope towards the Brahmaputra. There are swampy depressions here and there, which, with the accumulation of rain water and spills from the tributaries, do not drain speedily, as the drainage channels serving these are either of inadequate section or in a bad state and do not function properly. This results in the prolonged flooding of the marginal areas around these depressions. There are cases where several rivers join together forming pockets such as the Pagladiya-Baralia basin in north Kamrup area. Measures for the disposal of the flood congestion in such pockets do not seem to have been taken in hand yet. This has resulted in such pockets being adversely affected by prolonged flooding both due to breaches in the embankments and to spill from upstream reaches.

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*Report of the High Level Committee on Floods, Ministry of Irrigation and Power (1958).

SOIL CONSERVATION

10.78 Vast areas in the Brahmaputra basin are covered by hills in Assam, Meghalaya, Arunachal, Nagaland and West Bengal. Moreover, even the areas in the plains are continually subjected to erosion and floods by torrential streams. As such, the adoption of soil conservation measures is of vital importance for increasing and stabilising agricultural production in the basin.

10.79 In Assam, a separate Soil Conservation Department was set up in 1959 with a skeleton staff. Initially this department took up soil conservation work in the hill districts because of the harmful effects of soil erosion due to shifting cultivation in these areas. It was soon realised that in the plains districts, also, there were large tracts which were subject to accelerated erosion due to the extension of cultivation in the foot-hills, sheet and gully erosion on sloping land, and stream bank erosion due to rivulets often changing course and devouring fertile agricultural fields. Because of this, soil conservation work was also extended to the plains areas of the State by the establishment of three soil conservation divisions.

10.80 In the hills, the programmes were:

- (i) Demonstration of plantation of non-perishable perennial cash-crops like cashew-nut, coffee and black pepper.
- (ii) Experimental plantation of rubber, cardamom etc.
- (iii) Inducement to jhum cultivators to take up cultivation of cash crops by giving loans and subsidies for growing cashewnuts, coffee and black pepper.
- (iv) Terracing of hill slopes to convert them into permanent agricultural fields.
- (v) Afforestation of degraded hill slopes.
- (vi) Pasture development mainly by introducing exotic grasses and legumes.

10.81 In the plains, the programmes implemented were (i) gully control, (ii) terracing, (iii) afforestation of stream banks, (iv) pasture development of lands unsuitable for agriculture or too good for forestry and (v) stream bank erosion control.

According to the State Government, in future also, the programme will be essentially the same, with some shift in emphasis and larger coverage.

The emphasis in the hills will be on the Land Development Programmes comprising of terracing, contour bunding, water spreading etc. Other programmes will be afforestation, research, experiments, cash crop development on lands which cannot be developed for settled agriculture and pasture development. In the plains area of the State, the following programmes will be implemented: (i) gully control, (ii) terracing and contour bunding, (iii) afforestation on stream banks, (iv) stream bank erosion control through minor engineering structures and (v) pasture development.

10.82 Soil conservation measures of the type similar to the above but on a reduced scale are likely to be implemented by the Governments of Arunachal, Nagaland and Meghalaya which have similar problems and topography.

10.83 In West Bengal, a few soil conservation schemes mostly involving the stabilisation of slips in the Darjeeling district were taken up by the Department of Irrigation and Waterways during the Third Plan period. Of these, the Master Plan for soil conservation in catchment of the Lish, a tributary of the river Tista, is important. This scheme is still under execution.

Another proposal framed by the Forest Department and benefiting the Darjeeling Hills is the slope-stabilisation scheme, which has been considered by the Technical Expert Committee on Floods, North Bengal constituted by the Governmeht of India. The scheme envisages a coverage of 18,800 hectares at an estimated cost of Rs. 76.90 million. The works proposed are:

(i) Bench terracing;
(ii) Vegetative measures including afforestation, grass and shrub planting;
(iii) Jhora training and runoff controls which are proposed to be achieved by the adoption of (a) series of grade stabilisation structures, (b) paved channels, (3) spurs, revetment walls, drop structures etc., (4) diversion channels.

This scheme is intended to be a comprehensive one, covering agricultural lands, forest lands and lands under tea estates damaged by slips and also vulnerable areas all over the district.

GENERAL

10.84 The number and distribution of rain-gauge stations should be reviewed and new stations to fill in existing gaps should be established.

It is also important that the daily rainfall data for all these stations should be published on a monthly basis, preferably sub-basin-wise.

A network of evaporation measurement stations, particularly at the sites of existing and proposed reservoirs should be established.

Gauge and discharge observations of the various sites in the basin should be continued on a permanent basis to obtain data essential, not only for the preparation of individual projects, but also for the regulation, to the best advantage, of the available river waters in any year.

10.85 It is necessary for systematic data to be collected with regard to the sediment carried by the rivers, which would be of considerable use in working out dead-storage and the lives of reservoirs. It will also help to assess the effect of soil conservation works carried out in the basin.

SALIENT FEATURES OF THE BASIN OF THE BARAK AND OTHER RIVERS*

(i) Source:	The Barak	South of Mao Songsang in Manipur (Latitude 25°28′N, Longitude 94°18′E).
	The Gumti	Near Gunamanipara in Tripura (Latitude 23°42′N, Longitude 91°55′E).
	The Muhari	South of Palangphabari in Tripura (Latitude 23°13′N, Longitude 91°45′E).
	The Fenny	North of Diwanbari in Bangladesh (Latitude 23°19′N, Longitude 91°48′E).
	The Karnaphuli	East of Phuldungsei in Mizoram (Latitude 22°50′N, Longitude 92°17′E).
	The Kaladan	North of Hnahlan in Mizoram (Latitude 23°47′N, Longitude 93°23′E).
	The Imphal	North of Kangpokpi in Manipur (Latitude 25°13′N, Longitude 93°57′E).
	The Tixu Nantaleik	East of Longsa in Nagaland (Latitude 26°12′N, Longitude 94°45′E).

		Km.	Miles
(ii) Length:	The Barak	564	350
	The Gumti	118	73
	The Muhari	40	25
	The Fenny	36	22
	The Karnaphuli	144	89
	The Kaladan	290	180
	The Imphal	160	99
	The Tixu Nantaleik	148	92

(iii) Drainage Area:		sq. km.	sq. miles
Assam		28,890	11,155
Meghalaya		10,775	4,160
Manipur		22,347	8,628
Tripura		10,453	4,036
Nagaland		5,685	2,195
	Total	78,150	30,174

(iv) Population (1971 Census): 5.33 million.

(v) Density of Population: 68 per sq. km. 176 per sq. mile.

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*All statistics pertain to the part of the basin lying in Indian territory only.

(vi) Maximum discharge:	Cumecs	Cusecs
The Barak at Lakhipur in 1956	4,729	167,000
The Gumti at Sonamura in 1956	736	26,000
The Imphal at Sekmaijin in 1957	288	10,179
(vii) Minimum discharge:	N.A.	
(viii) Average annual runoff:	m.cu.m.	M.A.F.
The Barak upstream of Badarpurghat	41,188	33.39
	Thousand hectares	Thousand acres
(ix) Culturable area (1967-68)	1,114	2,753
(x) Net area sown (1967-68)	744	1,838
(xi) Gross area sown (1967-68)	925	2,286
(xii) Net irrigated area (1967-68)	110	272
(xiii) Gross irrigated area (1967-68)	120	297
(xiv) Area irrigated at the end of the Fourth Plan	187	462
(xv) Water utilisation, including reservoir losses, at the end of the Fourth Plan	m.cu..m 1,453	M.A.F. 1.18

N.A.—Not available.

CHAPTER XI

THE BASIN OF THE BARAK AND OTHER RIVERS

The basin of the Barak and other rivers extends over an area of 78,150 sq. km. The basin lies between east longitudes 90°10′ and 95°7′ and north latitudes 21°58′ and 26°24′. Lying in the eastern region, the basin covers large areas in the States of Assam, Meghalaya, Manipur, Tripura, Nagaland and Union Territory of Mizoram. The State-wise distribution of the area is given below:

Table 11.1

Drainage Area—Barak and Other Rivers

Name of State	*Drainage area in sq. km.*
Assam (including Mizoram)	28,890
Meghalaya	10,775
Manipur	22,347
Tripura	10,453
Nagaland	5,685
Total	78,150

11.2 The basin is bounded on the north by the Barail range separating it from the Brahmaputra basin, on the east by the Naga and Lushai hills, on the south and west by Bangladesh. It is irregular in shape with a maximum breadth of 350 km. in north-south direction and a maximum length of 460 km. in the east-west direction. There are two major physiographic divisions in the basin, namely, the hilly regions and the plains. The plains are thickly populated and extensively cultivated.

THE RIVER SYSTEM

11.3 The various river systems in the basin are:

1. The Barak
2. The Gumti
3. The Muhari
4. The Fenny
5. The Karnaphuli
6. The Kaladan
7. The Imphal
8. The Tixu Nantaleik

The main river systems are described briefly in the following paragraphs.

The Barak

11.4 The Barak rises in the Manipur hills, south of Mao on the Kohima-Imphal road, and flows in a south-westerly direction through a narrow valley up to Jirighat. It then turns west and emerges from the hills a few km. above Lakhipur. On emerging from the hills, it traverses the valley in a westerly direction up to Bhanga, a few km. below Badarpur, where it bifurcates into two branches, the Surma and the Kusiyara. The present border of the Cachar District of Assam lies along the eastern bank of the Surma and along the southern bank of Kusiyara up to a point 32 km. west of this bifurcation point.

The length of the river from its origin up to Lakhipur is 403 km., up to the border of Assam along the Kusiyara 564 km. and up to its outfall into the Meghna near Bhairab bazar in Bangladesh 902 km. As it flows down the valley, the Barak is joined by tributaries both from the north and the south. The main northern tributaries are the Jiri, the Chiri, the Modhura, the Jatinga, the Harang, the Kalain and the Gumra. The main south bank tributaries are the Sonai, the Katakhal, the Dhaleswari, the Singla and the Longai.

Up to Badarpur, the Barak has a catchment area of about 25,900 sq. km.

The Gumti

11.5 The Gumti is formed by the confluence of two streams, the Surma and the Rajma at Ducharibari. It flows throughout in a westerly direction in a well defined course. After passing through Rangamati, Sonamura and Durgapur towns, it crosses the international boundary and joins the Meghna.

Total drainage area of the Gumti in the Indian territory is 2,128 sq. km.

The Imphal

11.6 The Imphal rises in north Manipur and flows through the State Capital. It receives the Iril from the south and the Thoubal from the east. It also receives the Khuge from the south-west and is known as the Manipur river below its confluence. Three km. below Shuganu, the Imphal is joined by the Chakpi river flowing from the opposite direction and the combined waters flow southward through a narrow gorge to fall into the Chindwin river of Burma, some 320 km. lower down.

The Imphal drains a total area of 7,255 sq. km. within Indian territory.

11.7 The details of other important rivers in the basin are given below:

Table 11.2

Other River Systems

Name of the river	Source					Length in the Indian territory in km.	Drainage area in the Indian territory in sq. km.
	Place	State/ U.T.	Lat.	Long.	Elev. (m)		
1	2	3	4	5	6	7	8
Muhari	South of Palangihabari	Tripura	23°13′	91°45′	230	40	948
Fenny	North of Diwanbari	Bangladesh	23°19′	91°48′	287	36	555
Karnaphuli	East of Phuldungsei	Mizoram	22°50′	92°17′	450	144	3,999
Kaladan	North of Hnohlan	-do-	23°47′	93°23′	1200	290	7,933
Tixu Nantaleik	East of Longsa	Nagaland	26°12′	94°45′	1800	148	6,449

CLIMATE

11.8 During the year, four distinct seasons occur in the basin. They are (i) winter, (ii) summer, (iii) monsoon and (iv) post-monsoon.

The basin enjoys a sub-tropical and temperate climate.

The winter season begins in December and continues to the end of February. The winds blow mainly from the east towards the north-west. From March onwards is the summer season which continues till the end of the first week of May. The monsoon sets in by the last week of May and withdraws by the first week of October. Heavy rainfall occurs during these months. Generally July and August are the rainiest months. After the withdrawal of the monsoon by the middle of October, cyclonic storms from the Bay across the Bengal Coast bring clouds and rain. From November the weather clears up.

11.9 There are 59 reporting rain-gauge stations in the basin. The density works out to one station for every 1,325 sq. km. The number of gauges is, therefore, insufficient. Establishment of more rain-gauge stations to obtain a balanced distribution over the entire basin is necessary. In selecting the locations for new rain-gauge stations, care should be taken to see that all areas in the basin are suitably represented.

The rainfall data of all the rain-gauge stations are being observed and printed by the Rainfall Registration Authorities of the concerned States. This data appears in the annual volume of the daily rainfall of India compiled and issued by the Indian Meteorological Department. Such volumes are available since 1891. A major part of the basin receives rainfall of about 2,000 mm. The south-western and north-western parts of the basin receive a higher rainfall ranging from 2,000 to 3,000 mm. The monthly and annual normals of rainfall in the districts lying in the basin are shown in Table 11.3.

Temperature

11.10 During the winter season in January, the mean temperature over the major part of the catchment varies from 17.5°C to 20°C. The higher elevations in the hill ranges experience lower temperatures.

During the summer season in April, the mean temperature over the catchment varies from 25°C to 27.5°C. The temperature in the hilly regions is below 25°C.

In the rainy season, in the month of July, the mean temperature varies from 27.5°C to 30°C.

Towards the end of the monsoon season in the month of October, the

Table 11.3

Monthly and Annual Normals of Rainfall in the Basin of Barak and Other Rivers

State/District	Normals of Rainfall (mm)												Annual normals of Rainfall in mm
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Assam													
(i) Cachar	18.6	45.4	137.3	349.1	451.1	626.4	513.7	502.1	399.3	199.3	44.2	7.4	3,293.9
(ii) United Mikir & North Cachar Hills	18.8	41.2	137.1	320.6	435.2	637.0	460.4	418.4	337.8	201.2	56.3	7.8	3,071.8
Nagaland	22.9	53.8	85.0	166.1	276.2	402.9	452.1	427.3	294.6	144.5	41.0	11.0	2,377.4
Meghalaya													
(i) Garo Hills	12.8	20.0	40.4	159.3	375.4	557.2	502.3	474.1	375.4	198.4	20.8	2.2	2,738.3
(ii) United Khasi & Jaintia Hills	14.8	35.3	108.9	347.8	745.6	1557.8	1347.1	1103.7	740.9	289.4	47.4	6.1	6,344.8
Manipur	18.8	53.0	89.7	159.8	268.7	459.5	461.7	389.5	268.0	150.3	59.5	10.7	2,389.2
Tripura	9.7	29.7	55.4	165.5	329.1	421.5	336.1	322.1	245.5	142.2	39.9	4.0	2,100.0
Mizoram	15.5	35.3	72.1	184.8	316.9	525.1	498.2	483.8	420.6	190.6	58.8	20.4	2,822.1

Source: Memoirs of the India Meteorological Department; Vol. XXXI, Part III.

mean temperature over the basin varies from 25°C to 27.5°C. The hill-regions experience lower temperatures.

Evaporation

11.11 There are two departmental observatories at Agartala and Imphal and one agro-meteorological observatory at Karimganj, of the Indian Meteorological Department*. Limited data is available from these observatories.

SOILS

11.12 A soil survey of the area covered by the basin has not been made. However, the general data regarding the soils of India shows that mainly laterite, red and yellow soils occur in the basin. The principal soil types found in the various districts of the basin are shown below:**

Table 11.4

Soils of the Basin of Barak and Other Rivers

Name of the State/U.T./ District	Type of soil
Assam	
(i) Cachar	Red and yellow.
(ii) United Mikir and North Cachar Hills	Laterite and red and yellow
Nagaland	Laterite and red and yellow
Meghalaya	
(i) Garo Hills	Laterite and red and yellow
(ii) United Khasi and Jaintia Hills	Laterite and red and yellow
Manipur	Red and yellow
Tripura	Red and yellow
Mizoram	Red and yellow and red

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*Evaporation Data (India), India Meteorological Department (1970).

**Indian Crop Calendar, Directorate of Economics and Statistics, Min. of Food, Agri., C.D. & Cooperation (1967).

LAND USE AND AGRICULTURE PRACTICES

11.13 Land use details in the basin in 1967–68, the latest year for which the statistics are available, are given below:

Table 11.5

Land Use Details

Item	Area in thousand hectares					Total
	Assam (including Mizoram)	Nagaland	Meghalaya	Manipur	Tripura	
1	2	3	4	5	6	7
Geographical area	2,889	569	1,077	2,235	1,045	7,815
Reporting area	2,872	569	1,077	2,211	1,045	7,774
Area under forests	1,561	22	87	602	635	2,977
Area not available for cultivation	955	358	919	1,407	44	3,683
Culturable area	356	119	71	202	366	1,114
Uncultivated culturable area	114	103	—	23	130	370
Net area sown	242	16	71	179	236	744
Area sown more than once	63	1	9	9	99	181
Total cropped area	305	17	80	188	335	925
Net area irrigated	8.1	4.2	15.7	65.0	17.0	110.0
Gross area irrigated	8.1	4.2	15.7	75.0	17.1	120.1
Percentage of net area sown to culturable area	68.0	13.5	100.0	88.6	64.5	66.8
Percentage of net area irrigated to culturable area	2.9	3.5	22.1	32.2	4.6	9.9
Percentage of net area irrigated to net area sown	3.4	26.3	22.1	36.3	7.2	14.8

The culturable and the total cropped areas in the basin form 0.57 per cent each of the total culturable and cropped areas respectively of the country.

The general cropping pattern in the irrigated areas is described below:

In the part of basin lying in Assam, out of the total irrigated area of 8,100 hectares, 98.77 per cent is under paddy and the rest under other crops. Food crops cover 100 per cent of the irrigated area.

In the Nagaland part of the basin, the entire irrigated area of 4,200 hectares is under paddy.

In the Meghalaya part of the basin, the entire area of 15,700 hectares is under paddy cultivation.

Similar is the case in the total irrigated area of 75,000 hectares in the Manipur part of the basin.

In the part of the basin lying in Tripura, out of a total irrigated area of 17,100 hectares, 94.15 per cent is under paddy, 0.58 per cent under sugarcane and the rest under other crops. Food crops represent 98.25 per cent of the irrigated area, the balance of 1.75 per cent being under non-food crops.

11.14 Summing up, for the basin as a whole, of the total irrigated area, 99.08 per cent is under paddy, 0.08 per cent under sugarcane and the rest under other crops. Food crops cover 99.75 per cent of the irrigated area, the balance of 0.25 per cent being under non-food crops.

11.15 There are mainly 3 main crop seasons in the basin—(1) early kharif; (2) kharif; and (3) rabi. The details of the crops grown and their periods in the different crop seasons are shown below:

Table 11.6

Crop Seasons

Season	Crop grown	Period
1	2	3
Early kharif	Aus Paddy	April to June (90 days)
	Jute and Mesta	March/April to August/September (150 days)
Kharif	Aman paddy	August to November (120 days)
	Kharif pulses	August to October
	Cotton	August to November
Rabi	Boro paddy	December to March
	Potato and Tobacco	November/December to February
	Pulses and oil-seed	November to January
	Wheat (Very little quantity, just started on experimental basis)	November to March.

Sugarcane is also grown as an annual crop. The period for this crop is from January/February to October/November (270 days).

REGIONAL ECONOMY

Population

11.16 On the basis of the 1971 census* and the percentage of the area of each district within the basin to the district as a whole, the total population in the basin is about 5.33 million. There is no city in the basin which has a population of more than one lakh. The average density of the population in the basin is 68 persons per sq. km. against the figure of 182 for India as a whole. The density varies from region to region. Whereas the district of Cachar has the highest density of 246 persons per sq. km., the Mizo Hills district has the lowest density of 15 persons per sq. km. Of the total population in the basin, nearly 90 per cent of the people live in rural areas while the balance 10 per cent live in urban areas. The working force constitutes nearly 30.5 per cent of the total population. 59 per cent of the working force is engaged as cultivators and 9 per cent as agricultural labourers. The balance 32 per cent of the working force is employed on manufacturing and other tertiary activities.

Forests and Agriculture

11.17 In the basin forests occupy 38.29 per cent of the total area and the culturable area constitutes 14.33 per cent. Of the total culturable area of 1.11 million hectares nearly 0.93 million hectares are annually cultivated. An area of 0.12 million hectares constituting 12.98 per cent of the cultivated area is irrigated annually. Paddy is the most important irrigated crop in the basin covering nearly 99.08 per cent of the total irrigated area.

Power

11.18 The Central Water and Power Commission has indicated the hydroelectric power potential of the basin as 2,492 MW, when assessing the power potential of the country. At present, the demand for electrification for towns is mainly met by means of diesel plants. There are no major hydro and thermal power stations in the basin at present. The Loktak Lake Hydroelectric Project with an installed capacity of 70 MW in the first stage is under construction in the basin and is expected to be completed in the early part of the Fifth Plan period. The Gumti hydro-electric project, with an installed capacity of 10 MW is also under construction.

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*Census Paper I of 1971 (Supplement), Registrar General (India).

*Mineral Wealth**

11.19 *Petroleum* and *Coal* occur in the United Khasi and Jaintia hills district of Meghalaya and the Cachar district of Assam. *Limestone* is found in the United Khasi and Jaintia hills of Meghalaya and in the United Mikir and North Cachar hills of Assam.

In addition to the above, there are other minerals being explored by the Geological Survey of India in the different regions of the basin; but their economic exploitation lies in the distant future.

Industries

11.20 The only important industries in the basin are those of tea, plywood, hard and soft boards in Karimganj.

Communications

11.21 The basin is served by the network of the North East Frontier Railway with Headquarters at Pandu, near Gauhati. The railway lines in the basin connect Haflong-Silchar-Lalaghat-Karimganj, Karimganj-Dullabchara-Kalkali Ghat.

The main National Highway runs from north to south connecting Dimapur, Kohima, Imphal and Tamu. Other important places in the basin like Silchar, Agartala, Aijal, etc. are also connected by roads. The southern part of the basin, which mainly consists of the hilly regions, is very poorly served with communications. Because of the riverine character of the land, ferries still present serious bottlenecks in the free movement of goods and people.

The Barak is a very important navigable waterway in the basin. It is navigable throughout the year† by medium sized country boats from Lakhipur to Karimganj near the Bangladesh border, for a distance of about 153 km. Earlier, steamers of the Joint Steamer Companies used to operate from Calcutta to the Silchar Ghats (about 1,300 km.) during the monsoon. In the low water season, between October and April, the services used to be maintained by transhipping cargo at Markholi or Genchuganj to Feeder Service Steamers, small barges and launches which maintained the services between these two stations and Cachar. A feeder service by launches and barges operates between Silchar and Fullertol (Lakhipur), a distance of about 64 km., during the rains from July to September, for carriage of tea and stores. Small country boats also ply about 88 km. upstream and up to Tapaimukh during the monsoon. This reach forms the boundary of Assam and Manipur. There is not much traffic in this reach. Fruit and vegetables are transported by country boats from the interior to the towns. Small country boats also ply on some of the tributaries of the Barak in the plains catering to local needs.

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*Techno-Economic Surveys of Manipur, Tripura and Nagaland, NCAER.

†Navigable Waterways of India, Central Water & Power Commission (1961).

In general the plain and valley areas of the basin are better served with communications in comparison to the hilly areas which lack such facilities.

The economy of the basin largely depends on agriculture. With abundant rainfall and fertile valleys suitable for cultivation of a wide variety of crops, the potential of the basin for development and diversification of agriculture is great. However the progress of agriculture so far, has not been able to keep pace with the growth of population. The principal factor responsible for making agriculture unstable is the recurrence of floods.

WATER RESOURCES

Surface Water

11.22 In the irrigation potential studies made by the Central Water and Power Commission in 1960, the total annual run-off of the Brahmaputra, Barak and other basins had been assessed as 590,740 m. cu. m.*

The work of systematic observation of the discharges of the Barak and other rivers was taken up by the Central Water and Power Commission in 1954 and continued till 1963.

After February 1963, the work of discharge observations was handed over by the Central Water and Power Commission to the State Governments concerned who have since been collecting hydrological data. The details of the gauge and discharge sites maintained by the Assam State Govt. are shown in Table 11.7.

11.23 Under the programme of establishing and maintaining Centrally Sponsored Key Hydrological Stations in the country, the Central Water and Power Commission has proposed the inclusion of the following sites in the basin. (Table 11.8)

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*Report of technological possibilities of irrigation projects in India, Central Water & Power Commission. (Unpublished)

Table 11.7

Existing Gauge and Discharge Sites

Name of the river	Site	Years for which the data is available
1	2	3
Barak	U/S of Lakhipur	1956 to 1965
Barak	U/S of Badarpurghat	1961 to 1964
Sonai	U/S of Palonghat	1956 to 1959
Katakhal	U/S of Kukicherra	1957 to 1960

Table 11.8

Proposed Gauge and Discharge Sites

Name of the river	Site
1	2
Gumti	Sonamura
Imphal	Near Thoubal
Barak	Below confluence of Tuvair
Barak (Dhaleswari)	Below confluence of Cutir and Dhaleswari.
Barak	Below confluence of Dhaleswari.

The average annual flows of the different rivers as per the data furnished by the Assam State Government are given in Table 11.9.

Table 11.9

Seasonal and Annual Flows of Rivers

Name of the river	Catchment area in sq. km.	Normal rainfall in mm.	Average flow in m.cu.m.					Years for which the average has been worked out
			June-Sept.	Oct.-Dec.	Jan.-March	April-May	Total	
1	2	3	4	5	6	7	8	9
Barak	13,209 (U/S of Lakhipur)	2820-3050 in valley & 4320 in the basin	12,689	2,877	373	1,069	17,008	1956 to 1965
Barak	23,750 (U/S of Badarpurghat)	-do-	27,621	8,812	1,416	3,339	41,188	1961 to 1964
Sonai	1,552 (U/S of Palonghat)	2750	1,393	373	57	116	1,939	1956 to 1959
Katakhal	3,104 (U/S of Kukicherra)	2900	2,395	809	105	187	3,496	1957 to 1960

Ground Water

11.24 The Barak drainage system originates in the Tertiary and Cretaceous ranges of Assam and Manipur.* After a south-westerly flow through Tertiary and early Quaternary sediments in the Silchar district, the river basin merges into the recent alluvial plains of the Upper Meghna in Bangladesh. No surveys or explorations have been conducted. Geohydrologically the area appears promising from the point of ground water utilisation. Any ground water development programme in this region has to be balanced against the prospects of water-logging in susceptible localities with sub-surface or geomorphic peculiarities and also in areas prone to surface flooding. Proper delineation of these areas along with their reclamatory or protective measures are necessary in the first instance, before any ground water utilisation is attempted. From the point of view of quality, except for a high dissolved iron content at places, no problems of salinity are expected, in view of the high incidence of rainfall and the high permeability of the granular formations, mostly under water table conditions.

In hard consolidated rocks like Archaeans, Sylhet traps, etc. the occurrence and movement of ground water are restricted and no large scale development is feasible. In these areas it is possible to utilise ground water either by harnessing the springs or by putting large diameter open wells to tap weathered zones.

In the Tripura area, fine to coarse, poorly consolidated sandstones and clayey sandstones of the Tipam series and post-Tipams constitute the chief aquifers. Ground water occurs both under water table and confined conditions and is tapped by open wells and tubewells respectively. The quality of water is good except for a slightly high content of iron at places. At present, ground water is used mainly for domestic purposes and irrigation. There is enough scope for the development of ground water in the area.

The Manipur valley is a closed basin. Assorted sediments consisting of gravels, pebbles and coarse sand form the aquifers. The chemical quality of water is good and is suitable for public health, irrigation and other purposes. At present ground water is used mainly for domestic purposes.

The investigations carried out so far point to the urgency and importance of carrying out further systematic exploratory work in the basin for making a scientific, qualitative and quantitative assessment, which will help in framing a rational plan of development of ground water for various needs.

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*Ground Water Resources of India, Status and Surveys, Prospects & Perspectives, Geological Survey of India (August, 1970).

EXISTING DEVELOPMENT

11.25 Irrigation in the basin is mainly from minor irrigation works, especially in the Tripura and Manipur areas. There are no major or medium projects. A few diversion and lift schemes, the latter worked with the help of diesel generations ranging from 5 to 20 H.P., irrigate areas in Manipur and Tripura. Further in the valley portion, private canals from small hill streams also provide irrigation facilities. The Indian Irrigation Commission (1901–03) has not recommended any particular project to be taken up in this basin.* No major or medium irrigation projects have been taken up during the Plan periods.

The details of the area irrigated by various sources in the basin during 1967–68 are given below:

Table 11.10

Source-wise Irrigation

Source of irrigation	Area irrigated ('000 hectares)					
	Assam (including Mizoram)	Nagaland	Meghalaya	Manipur	Tripura	Total
1	2	3	4	5	6	7
Canals	2.8	—	—	—	—	2.8
Tanks	—	—	—	—	1.8	1.8
Other sources	5.3	4.2	15.7	65.0	15.2	105.4
Total	8.1	4.2	15.7	65.0	17.0	110.0

In the absence of data, regarding the annual diversions and utilisations, etc., the utilisation has been approximately estimated, by the Commission based on rough data. It may be of the order of 855 m. cu. m. including reservoir losses.

By the end of the Annual Plan (1968–69), the area under minor schemes increased by about 14,610 hectares requiring nearly 113 m. cu. m., including reservoir losses.

Thus, up to the end of the Annual Plan (1968–69), about 968 m. cu. m. of waters have been used for irrigating a total area of 124,610 hectares.

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*Report of the Indian Irrigation Commission (1901-03).

The industrial needs for water in the basin are insignificant. There is no problem of water pollution caused by the discharge of industrial wastes.

FUTURE DEVELOPMENT

11.26 No major or medium irrigation project is proposed to be taken up for construction in the basin in the Fourth Five Year Plan period. Concerned State Governments have also not indicated any future projects in the basin.

During the Fourth Plan, the area under the minor schemes is expected to increase by about 62,310 hectares requiring nearly 485 m. cu. m. including reservoir losses.

Thus, up to the end of Fourth Plan, about 1,453 m. cu. m. of waters would have been used for irrigating a total area of 186,920 hectares.

Currently two major hydel schemes are under construction, namely, the Loktak Lake project in Manipur across the Manipur river and the Gumti hydel project in Tripura. Both projects envisage secondary benefits in the shape of lift irrigation, from the assured tail race discharges.

11.27 The Loktak Lake H. E. Project will be the first phase of the Loktak multipurpose scheme. In this phase, 10.67 m. high and 8.23 m. long barrage will be constructed across the river Manipur at Ithai.* The installed capacity of the power house will be 70 MW. The cost of the project has been estimated to be Rs. 102.5 million. The work on the project was started in 1969 and is expected to be completed early in the Fifth Plan.

The lift irrigation system to serve 24,281 hectares which is to come up later will utilise 16.99 cumecs of controlled discharge.

11.28 Similar attempts have been made by the Tripura State on the Gumti river. The project will consist of a brick concrete dam 29.9 m. high at Dumbra falls site. The power generation will be 10 MW at 50 per cent load factor. The continuous tail race discharge of 12.74 cumecs could be used for lift irrigation of about 8,094 hectares.

11.29 There is immense hydro-potential on most of the rivers which ultimately join the rivers Meghna, Barak, Manipur and Chindwin. As and when the H.E. schemes come into operation, there will be assured flows from the tail-races of the power houses, and also power, which could be used locally for lift irrigation and for stabilising the rabi crops. With a modified crop pattern including fruits and vegetables instead of only rice as at present, agro-based industries can be developed. With the lift irrigation facilities in the tribal areas the present jhuming cultivation will get discouraged and this will lead to better soil conservation programmes, lesser silt loads and flood hazards.

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*Cyclostyled hand out of comments on the 70 MW Loktak Lake Project, Manipur, by the Central Water and Power Commission (Power Wing).

FLOODS, WATERLOGGING & DRAINAGE

11.30 The main flood problem of the Barak is typified by:

(i) Spilling over banks and submerging low lands.
(ii) Backing up effect of the main river on its tributaries.
(iii) Some erosion on the river and its tributaries mainly due to sloughing of banks during subsiding stage of floods.

The heavy rainfall averaging 2,286 mm. or more, combined with the main river and 'Chhara' beds agraded due to silt deposition year after year, cause floods which inundate large tracts of cultivated areas on the margin of rivers. This affects the crops and habitation to a large extent, though flood control works in the shape of marginal embankments, etc., are continuously being put up in the acutely affected reaches.

Many depressions remain waterlogged even after the monsoon. The floods have become an annual feature since the 1950 earthquake, which has raised the bed level of several 'chharas' and rivers. The dykes have afforded partial relief from floods in the past; but a lasting solution, which would mean holding back the high flood flows in storages and controlling the silt loads through Soil Conservation measures in areas where forests have been cut for cultivation, is yet to be formulated.

The Barak is erratic in its behaviour during the rainy months of June to September. Sudden rises of 3 m. to 4.6 m in the river levels occur in a matter of a few hours. Such abrupt rises cause a reversal of the flow in the tributaries, especially, in the flat reaches, beyond the confluence with the Jiri. The floods usually affect Silchar and other sub-divisions of the Cachar district (between Lakhipur and Karimganj). Flood damages have been estimated to vary from Rs. 0.1 million to more than Rs. 1.5 million in some years. From 1960 onwards, investigations for a suitable storage site on the Barak, which would effectively control the floods, have been made.

11.31 So far, three locations have been examined viz. Maindhar, Narayandhar and Bhubhandhar. The Maindhar and Bhubhandhar sites are located upstreams of the confluence with the Jiri, whereas the Narayandhar site is below it. The Maindhar site has been given up due to unsuitable foundations. Preliminary investigations and designs have indicated that at the Narayandhar site, a 49.38 m. high dam would store 4,070 m. cu. m., of which 2,948 m. cu. m. can be the live storage. Silchar town being the vulnerable point, the river level at that place is to be restricted to 19.81 m. or lower corresponding to a total discharge of 6,966 cumecs, made up of a controlled discharge of 3,610 cumecs from the reservoir and an uncontrolled discharge of 3,356 cumecs drained by the intermediate catchment of 4,382 sq. km. from the dam to Silchar. Such a reservoir would submerge about 30,756 hectares in the States of Assam and Manipur, the later suffering more though it would enjoy no benefits from the project.

11.32 To reduce the problem of submersion in Manipur State to the minimum, an alternative site has been considered upstream of the confluence with the Jiri, at Bhubhandhar. Here, the earth dam would be about 61 m. high and 400 m. long. The catchment area up to the dam is 13,339 sq. km. The gross storage capacity of the reservoir would be 4,009 m. cu. m. at F.R.L. + 64.50 m. and the total submersion will be 16,390 hectares of which 7,731 hectares will be in Manipur State, which is substantially lower compared to the Narayandhar site. Power to the extent of 40 MW at 100% load factor will also be generated. Seasonal power generation is also possible. The installed capacity of the power station is 185 MW. When the power becomes available, it would be feasible to have lift irrigation schemes.

11.33 The case of the Manipur river, is slightly different because of the centrepetal drainage characteristics of the valley and the fact that the Loktak Lake intercepts the river. This lake has a water spread of 78 sq. km. in the dry period and 259 sq. km. during the rainy months. Valuable land covering nearly 16 to 18 thousand hectares is submerged during the rainy season. To prevent this submersion, the diversion of the river outside the basin has been investigated.

11.34 In the case of the Gumti, a project has taken shape. Regarding the other streams viz., the Karnaphuli and the Kaladan, investigations and drawing up of plans for suitable flood control measures are in various stages of completion.

SOIL CONSERVATION

11.35 The basin has 38.29 per cent of its area under forests. This percentage is quite high when compared to the all-India average. The major problem in the hill areas of the basin is that of shifting cultivation locally known as jhuming. In this method of cultivation, the forest is cleared and the debris burnt. A subsistence crop is then grown for about two years with the minimum of trouble, by using hand tools. The removal of the forest or bush cover by felling and burning, with the resulting exposure of the bare soil to rain and sun causes enormous soil losses, especially on hill sides. Not only are the surface layers of the soil often washed away, almost completely, but the plant nutrients locked up in the forest areas are largely lost. It is reported that about 207,287 hectares in the entire State of Assam, 46,963 hectares in Tripura and 21,862 hectares in Meghalaya are under such shifting cultivation.* In the shifting cultivation areas, the density of population is relatively low.

11.36 The reclamation of land subject to shifting cultivation consists largely in persuading the tribals to follow the practice of permanent agriculture. The only logical approach to achieve this end seems to be to prove to the 'Jhum' cultivators through demonstration farms, the superiority of permanent agriculture as a means of livelihood and to provide the necessary conditions under which settled agriculture can be practised profitably by them. For the purpose of settled agriculture, areas should be carefully selected so that adequate water resources and transport facilities are available. Its cropping pattern should include the growing of fruits and vegetables as a significant component. In addition, mixed farming should be encouraged with special emphasis on poultry. A block of forests should also be attached to every settlement from which the settlers should be free to gather minor forest produce on payment of a nominal sum. Also, the Government should undertake the responsibility of levelling the land intended for settlement in the initial stages and to implement other soil conservation measures. A major part of the process of getting 'Jhum' cultivators to settle down is to convince them that the change is for the better. It must be remembered that demonstration farms by themselves may not produce the desired results. Though the tribal people engaged in shifting cultivation have, in most cases, come in contact with permanent cultivation and may even be aware of its advantage, the system is basically alien to them and there is a built-in social resistance. To overcome this resistance, it may be useful to impart to them a sense of participation in the demonstration farms by employing them as hired labourers and more significantly by associating their social leaders with the organisation of the farms.

11.37 Limited data is available regarding the silt loads carried by the rivers in the basin. For the conservation of river supplies and the establishment of the storage capacities to be created in the reservoirs, it is important that soil conservation measures are undertaken in the basin.

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*Land and Soil by S. R. Raychaudhuri (1966).

Under the Centrally Sponsored Programme of Soil Conservation in the catchments of major river valley projects, no scheme in the basin has been included.

GENERAL

11.38 More rain-gauge stations to obtain a balanced distribution over the entire basin need to be established. Rainfall data of all the stations should be collected in a scientific and systematic manner and published preferably monthwise.

Evaporation measuring stations may be established at the sites of the proposed reservoirs.

Gauge and discharge observations at the various sites should be continued on a permanent basis to obtain data essential not only for the preparation of individual projects but also for the regulation of the waters available. The rivers ungauged at present should also be gauged continuously and systematically.

11.39 Systematic and scientific exploratory work is needed for a quantitative and qualitative assessment of the ground water resources in the basin, so that these resources can be exploited in a rational way, either independently or in conjunction with surface waters.

11.40 There is need for taking up soil conservation measures in the basin.

SALIENT FEATURES OF THE WEST FLOWING RIVERS BASIN

		Sq. km.	Sq. Miles
(i) Drainage area:			
Tamil Nadu		4,702	1,815
Kerala		35,925	13,871
Mysore		25,095	9,689
Goa		3,610	1,394
Maharashtra		32,573	12,576
Dadra & Nagar Haveli		489	189
Daman		57	22
Gujarat		9,666	3,732
	Total	112,117	43,288

(ii) Population (1971 Census)		40.55 millions	
(iii) Density of population:	362 per sq. km.	920 per sq. mile.	
		m.cu.m.	MAF
(iv) Average annual runoff		217,894	176.65
		Thousand hectares	Thousand acres
(v) Culturable area (1967-68)		6,279	15,516
(vi) Net area sown (1967-68)		4,338	10,720
(vii) Gross area sown (1967-68)		5,152	12,731
(viii) Net area irrigated (1967-68)		660.7	1,632.6
(ix) Gross area irrigated (1967-68)		875.8	2,164.2
(x) Area irrigated after completion and full development of Fourth Plan Projects		1,630	4,027
(xi) Probable additional irrigation by future projects		N.A.	
(xii) Water utilisation including reservoir losses		m. cu. m	MAF
(a) From major, medium and minor projects under operation and construction		13,467	10.92
(b) On completion and full development of Fourth Plan Projects		19,611	15.90

CHAPTER XII

THE BASIN OF THE WEST FLOWING RIVERS BETEWEN KANNIYAKUMARI AND THE TAPI

The basin extends over an area of 112,117 sq. km., and lies between east longitudes 72°43′ and 77°35′ and north latitudes 8°4′ and 21°10′. Located in southern and western India, the basin covers practically the whole of Kerala, Goa, Daman, Dadra & Nagar Haveli and parts of Tamil Nadu, Mysore, Maharashtra and Gujarat. The state-wise distribution of the drainage basin is given below:

State	*Drainage area* (sq. km.)
Tamil Nadu	4,702
Kerala	35,925
Mysore	25,095
Goa*	3,610
Maharashtra	32,573
Dadra & Nagar Haveli*	489
Daman*	57
Gujarat	9,666
Total	112,117

*Union Territories

12.2 The basin is bounded on the north by the ridge separating it from the Tapi basin, on the east by the Western Ghats, on the south by the Indian Ocean and on the west by the Arabian Sea. The basin is irregular in shape and has a maximum length of 1,555 km. in the NW-SE direction and a maximum width of 125 km. in the NE-SW direction.

THE RIVER SYSTEM

12.3 The basin is traversed by many small and fairly big rivers. There are as many as 115 rivers, of which one in Tamil Nadu, 32 in Kerala, 10 in Mysore, 3 in Goa, 11 in Maharashtra and 5 in Gujurat are the more important. 14 of these rivers are described below.

The Pamba is the third longest river of Kerala. It is 177 km. in length with a total drainage area of 1961 sq. km. It is formed by the confluence of the Pamba Aar, Kakki Aar, Arudai Aar, Kakkad Aar and Kall Aar. The Pamba Aar in turn is formed by several streams which have their origin in the Pulichi Malai, Naga Malai and Supndara Malai in the Peermade Plateau at an altitude of about 1,676 m. above M.S.L. The Kakki Aar which forms the major tributary of the Pamba river, is a much longer and larger stream to begin with than the main river. The Pamba river, after receiving the Kakki Aar, flows in a westerly direction till it is joined by the Arudai Aar. At Narayanamuzhi, it turns and follows a south-eastern direction until the Kakkad Aar joins it. Beyond the confluence the river flows in a southerly direction up to Vadasherrikkara where it is joined by the Kall Aar, which has its origin in the Valanjakkatti Malai. At Pandanad, the river bifurcates one branch taking a westerly course. The Manimala joins the Pamba in its Nirettupuram branch. The river thereafter flows northwards and falls into the Vembanad lake through several branches, the more important of which are the Pallathuruthy Aar, the Nadumudy Aar and the Muttar.

The Periyar 228 kms in length, is the second longest river of Kerala. It rises from the forest-clad Sivagiri peak, 80 km. south of Devikulam at an elevation of 2,438 m. above sea level. It traverses steep cliffs before it is joined at about 16 km. downstream by the Mullayar. The river then turns due west and continues to flow in that direction for about 16 km. in a sandy bed. About 11 km. below its confluence with the Mullayar, the river runs through a gorge. After a winding course of 13 km., the river reaches Vandiperiyar and then passes through another narrow gorge, below which it is joined by the Perumthura. Further down, it is joined by the Kattupanayar and then by the Cherutoni, Chittar, Perinjankutty, Muthirapuzha and Deviar. Flowing through Nariamangalam, the Edamala river joins the Periyar 13 km. lower down. Passing Malayattur and thereafter taking a meandering course the river reaches Alwaye where it divides itself into two branches. The principal branch flowing north-west, joins the Chalaukdi river at Puthenvelikara and then expands to a broad sheet of water at Munambham. The other, taking a southerly course, is broken up into a number of small channels which fall into the Vembanad lake at Varapuzha. The total drainage area of the river is 5,243 sq. km., of which 113 sq. km. lie in Tamil Nadu.

The Bharathapuzha, known as the Ponnani in the lower reaches, is the longest of the Kerala rivers. The main river, with a length of 251 km., originates in the Anamalai hills, at 610 m. above M.S.E. and flows through the Pollachi taluk of Tamil Nadu and Palghat, Walluvanad and Ponnani taluks of Kerala. Its drainage area is about 5,397 sq. km., of which 1,563 sq. km. lie in Tamil Nadu and the balance in Kerala. The river joins the Arabian Sea near Ponnani town. Its important tributaries are the Gayathripuzha, the Kannadi (also known as the Chitturpuzha, and the Amaravathi), the Korayar (or Kalpathipuzha) and the Thuthapuzha.

The Chaliyar, known in the lower reaches, as the Beypore is one of the major rivers of Kerala. The main river starts from the Elambalari Hills at an altitude of 2,067 m. It is formed by the confluence of numerous streams and rivers. Its important tributaries are the Cherupuzha, the Iringipuzha, the Kurumbanpuzha, the Kanhirapuzha, the Punnapuzha, the Karimpuzha, the Vadapurampuzha, and the Chaliyarpuzha. The Chaliyar flowing for a total length of about 169 km., finally joins the Arabian Sea at Beypore. The river drains a total area of about 2,788 sq. km. of which 373 sq. km. lie in Tamil Nadu.

The Netravati rises between Kudremukh and Ballalrayan Durga in the South Kanara district of Mysore at an elevation of about 1,000 m. at 75°20′ east longitude and 30°10′ north latitude and flows in a generally north-south direction for 40 km. up to Gohattu, where it takes a turn towards the west and flows in a generally east-west direction practically up to its outfall into the Arabian Sea near Mangalore. The Kumaradhari is its major left bank tributary joining it near the village of Uppinangadi. With a total length of 103 km. from its source to the outfall, the river drains an area of 3,657 sq. km.

The Sharavati has its source at Humacha in Shimoga district, 75°12′ east longitude, 13°53′ north latitude at an elevation of about 700 m. It flows in a generally south-north direction, for about 13 km. up to Riponpet. Thereafter, after being joined by various small streams and tributaries it merges into the Linganamakki reservoir. Thereafter the river flows in a generally north-west direction. In this reach are the world famous Jog Falls. The rain then flows in an east-west direction to its outfall in the Arabian Sea near Honavar. The total length of the river is about 122 km. and its catchment area about 2,209 sq. km.

The Gangavali known as the Bedti in its upper reaches rises about 7 km. south of the district town of Dharwar in Mysore State at 75°2′ east longitude and 15°23′ north latitude at an elevation of about 700 m. The river flows in a south-east direction for about 12 km. up to Hubli, whereafter its flow for about 72 km. is north-south. Further on it takes a turn towards the south-west. Many small streams join the main river which takes an east-west direction only a few km. before its outfall, into the Arabian Sea near Gokarn. Flowing for a total length of about 152 km., the river drains a catchment of about 3,902 sq. km.

The Kalinadi rises near the village of Bidi in the Belgaum district of Mysore State at 74°42′ east longitude and 15°33′ north latitude at an elevation of about 600 m. The river known as the Dogi in its upper reaches flows generally in a south-east direction for about 56 km. up to a point to the west of the village of Devikop. Beyond this point it flows in a generally south-east direction for 66 km. About 31 km. east of the village of Kadra, the river takes a generally east-west direction and outfalls into the Karwar Bay of the Arabian Sea, near the town of Karwar. The Pandhri is one of its important tributaries. With a total length of about 153 km. the river has a drainage area of 5,179 sq. km.

The Mandavi is an important river of Goa which rises about 10 km. north-east of Sonsagar in Belgaum district of Mysore State at an elevation of about 600 m. at 74°23′ east longitude and 15°33′ north latitude. One of its branches outfalls into Rachol near Dabolim. The main river however, outfalls into the Marmagao Bay (in the Arabian Sea) near Panjim, the capital of Goa. The river has a length of 87 km. and its catchment area is 2,032 sq. km.

The Savitri rises to the east of Varandha in district Kolaba of Maharashtra State at 73°40′ east longitude, 18°9′ north latitude at an elevation of about 600 m. It flows in a generally south-western direction to outfall into the Arabian Sea near the village of Devgarh. It has five tributaries, three of which join it on the right bank and two on the left bank. The total length of the river is about 80 km. and its catchment area is 2,257 sq. km.

The Ulhas rises near the village of Lonauli in the district of Poona in Maharashtra State at 73°23′ east longitude, 18°45′ north latitude, at an elevation of 600 m. With a small bend near Karjat, the river flows for about 32 km. in a south-north direction up to Vangani where it marks an S-turn. It then flows for about 24 km. till it crosses the Kalyan Bosai road. Five small streams join the river on its right bank up to this reach. The river then follows a serpentine course in the east-west direction till it bifurcates near the Dombivli tunnel, one branch flowing north and the other south. Two of its important tributaries, the Bhatsai and the Kalu join it near Titwala and their combined waters join the Ulhas just north of Kalyan. The main i.e. the northern branch of the river outfalls into the Arabian Sea opposite the port of Bassein. With a length of 122 km., the river drains an area of 4,637 sq. km.

The Vaitarna rises north of the village of Jarvar in Nasik district of Maharashtra State at an elevation of 800 m., 73°30′ east longitude and 19°54′ north latitude. It flows for about 20 km. in a generally north-south direction with one sharp bend, whereafter it follows a south-west course for about 42 km. up to the village of Vada. About 6 km. lower down, the Pinjal joins from the right. The river flows for another 19 km. in a generally east-west direction up to the village of Gorba where it changes its direction to north-west to flow for about 13 km. up to the village of Manor. Here the river again takes a short bend towards the south-west for about 10 km. where two tributaries join it, one from the north and the other from the south. The river now flows in a north-south direction for about 14 km., makes a semi-circle and outfalls into Agashi Bay of the Arabian Sea under the Dahisar Bridge of the Western Railway. The total length of the river is 126 km. and its catchment area 3,837 sq. km.

The Ambika rises near the village of Jamdar in the Dangs district of Gujarat State at 73°48′ east longitude and 20°37′ north latitude at an elevation of 600 m. The river flows in a generally north-westerly direction for 36 km. up to the village of Pimpri. Thereafter the direction of flow is generally east-west, for about 85 km. The river then makes a circle and flows in a north-south direction till Billimora, receiving two tributaries from the south. Flowing in an east-west direction for another 16 km., the Ambika outfalls into the Gulf of Cambay. With a total length of 142 km. the river drains an area of 2,715 sq. km.

The Purna rises just north-west of the village of Varse in district Dhulia of Maharashtra State at 73°57′ east longitude and 20°58′ north latitude at an elevation of 500 m. The river flows in a generally east-west direction for 40 km. and then takes a turn towards the north-west. About 14 km. lower down a tributary joins it on its right bank. Flowing on in an east-west direction it receives another tributary from its left, near the village of Ranvery. Then taking a sharp bend and flowing westwards it outfalls into the Gulf of Cambay near Matwad. The river has a length of 142 km. and drains an area of 2,431 sq. km.

12.4 Salient features of the other 48 important rivers in the basin are given in Table 12.1.

CLIMATE

12.5 The climate of the basin is mainly of the coastal type where the seasonal variation is generally small and the atmosphere is moist or humid.

The climate along the coastal belt is generally hot with a high degree of humidity reaching up to 90 per cent. In the mountainous region temperatures are quite low. The summer and winter climate is controlled by the south-west and north-east monsoons and the autumn and spring are practically indistinguishable. By December, the winter sets in.

The coastal region of Mysore has a temperate climate where the daily range of temperature is as little as 4°C.

Rainfall

12.6 The basin comes under the direct influence of the south-west

Table 12.1

Other River Systems

Sl. No.	Name of River	Source					Length Km.
		Place	Distt.	Lat.	Long.	Elevation	
1	2	3	4	5	6	7	8
	Tamil Nadu						
1.	Kodaiyar	S. of Kalakkadu	Kanniyakumari	8°28′	77°27′	1,500	56
	Kerala						
2.	Neyyar	E. of Parattipalli	Trivandrum	8°32′	77°17′	1,200	45
3.	Karamana	Agastya Malai	Trivandrum	8°37′	77°13′	1,200	48
4.	Attingal	E. of Kallar	-do-	8°42′	77°10′	1,200	54
5.	Ittikara	E. of Kadakkal	Quilon	8°48′	77°2′	150	54
6.	Kallada	S.E. of Kolattupuzha	-do-	8°50′	77°15′	900	92
7.	Achankovil	S. of Devar Malai	-do-	9°10′	77°15′	1,500	138
8.	Manimala	Pirmed	Kottayam	9°37′	76°54′	900	102
9.	Meenachil	E. of Erattupetta	-do-	9°40′	76°52′	900	61
10.	Muvattupula	E. of Erattupetta	-do-	9°43′	76°53′	1,200	92
11.	Chalakudy	N. of Valparai	Coimbatore	9°23′	76°57′	1,200	109
12.	Karuvannur	N. of Kallana	Trichur	9°25′	76°35′	900	60
13.	Keecheri	N. of Pattikad	-do-	10°37′	76°20′	150	48
14.	Tirur	W. of Valancheri	Calicut	10°53′	76°2′	80	30
15.	Kadalundi	E. of Karuvarakkundu	-do-	11°8′	76°15′	900	86
16.	Kallay	W. of Pundup-padi	-do-	11°31′	75°55′	900	40
17.	Korapuzha	W. of Pundupaddi	-do-	11°30′	75°52′	600	35
18.	Murat	N. of Pundupaddi	-do-	11°33′	75°57′	1,000	62
19.	Mahe	S.E. of Periya	Cannanore	11°48′	75°47′	900	42
20.	Tellicherry	E. of Kuttuparamloa	-do-	11°48′	75°42′	300	24
21.	Anjara Kandy	S. of Periya	-do-	11°49′	75°45′	700	52
22.	Valapattanam	S. of Ammatti	Coorg	12°13′	75°52′	900	101
23.	Kuppam	W. of Kakkabe	-do-	12°17′	75°32′	900	60

Table 12.1—contd.

Sl. No.	Name of River	Source					Length Km.
		Place	Distt.	Lat.	Long.	Elevation	
1	2	3	4	5	6	7	8
24.	Penuvamba	E. of Peringom	Cannanore	12°13′	75°22′	150	40
25.	Karingote	W. of Kakkabe	Coorg	12°18′	75°32′	600	52
26.	Nileshwar	NE. of Hosdrug	Cannanore	12°22′	75°12′	200	32
27.	Chandragiri	W. of Mercara	Coorg	12°27′	75°38′	600	92
28.	Shiriya	Bellare	South Kanara	12°38′	75°21′	100	56
29.	Uppala	W. of Puttur	-do-	12°46′	75°9′	100	42
	Mysore						
30.	Gurpur	W. of Ballalrayan Durga	South Kanara	13°10′	75°12′	600	70
31.	Swarna	N.E. of Karkal	-do-	13°17′	75°8′	300	60
32.	Sita	E. of Perduru	-do-	13°22′	75°7′	600	60
33.	Varahi	Kavaledurga	Shimoga	13°43′	75°5′	600	66
34.	Chakranadi	E. of Kodachadri	-do-	13°53′	74°55′	600	52
35.	Tadri	Sirsi	North Kanara	14°35′	74°50′	500	84
	Goa						
36.	Rachol	S.E. of Sanguem	Goa	15°10′	74°18′	450	64
37.	Chapora	S.W. of Belgaum	Belgaum	15°47′	74°20′	600	70
	Maharashtra						
38.	Gad	S.W. of Digvala	Ratnagiri	16°10′	73°57′	600	66
39.	Vaghotan	W. of Ranewadi	Kolhapur	16°40′	73°50′	450	66
40.	Machkandi	S. of Vishalgarh	Ratnagiri	16°52′	73°45′	150	58
41.	Kajvi	E. of Vishalgarh	-do-	16°55′	73°47′	450	58
42.	Shantri	E. of Sakharpa	-do-	17°0′	73°48′	300	92
43.	Vashishti	S.W. of Alore	-do-	17°26′	73°42′	900	68
44.	Kundalika	N.E. of Kolad	-do-	18°29′	73°25′	450	65
45.	Amba	E. of Jambaltulpada	-do-	18°42′	73°22′	450	74
	Gujarat						
46.	Damanganga	W. of Waghad	Nasik	20°12′	73°35′	600	118
47.	Par	Sarad	-do-	20°27′	73°42′	900	108
48.	Mindhola	E. of Amba	Surat	21°7′	73°37′	300	114

monsoon and receives heavy and assured rainfall between June and August. The rainfall gradually decreases from Kerala in the south to Gujarat in the north. In Kerala the period of the south-west monsoon is from June to September and of the north-east monsoon from September to November. The south-west monsoon rainfall is usually very heavy (about ⅔rds of the annual rainfall) and that of the north-east monsoon somewhat uncertain. 90 per cent of the rainfall occurs from June to November. During the north-east monsoon, precipitation is in the afternoons. During this season the sky is cloudy, the air humid and there is gusty and squally rain. In Tamil Nadu district of the basin also, the contribution of the north-east monsoon is as high as 28 to 45 per cent. The rest of the rainfall is accounted for by the south-west monsoon. In Mysore, the length of the rainy season increases from five months in the north to seven months in the south and there are as many as 15 to 25 rainy days in a month.

12.7 There are at present 265 reporting rain-gauge stations inside the basin. The density works out to one station for every 423 sq. km. The number of gauges appears to be adequate. The rainfall data of all the existing rain-gauge stations are being observed and printed by the rainfall registration authorities of the concerned States. This data appears in the annual volumes of the Daily Rainfall of India compiled and issued by the India Meteorological Department. Such volumes are available for the years since 1891. The major part of the basin receives over 1500 mm. of rain with five districts in Kerala, one district of Maharashtra and one district of Mysore receiving more than 3,000 mm. The monthly and annual normals of rainfall in the various districts lying in the basin are given in Appendix 12.1.

Temperature

12.8 In January during the winter season, the mean variation in temperature over the catchment is 20.0°C. The northern portions of the basin experience lower temperatures than the southern.

May is generally the hottest month of the summer. The mean temperature over the basin varies from 27.5°C to 30°0C and goes up to 32.5°C in parts of Gujarat.

In the monsoon and post-monsoon seasons, temperatures are moderate and in the range of 25.0° to 27.5°C. In the northern parts, however, temperatures are above 27.5°C.

Evaporation

12.9 Practically no data on evaporation is available for the basin. The

India Meteorological Department has compiled the evaporation data in respect of 30 departmental observatories and 48 agro-meteorological observatories scattered all over the country with data for more than five years. Of these, two departmental observatories are located at Bombay and Trivandrum and five agro-meteorological observatories at Karjat, Kasaragod, Pattambi, Ollukara and Kayangulam in the basin.*

SOILS

12.10 No systematic soil survey of the basin has been carried out so far. The general data regarding the soils of India, however, indicates that the basin consists mainly of red loamy soils, red sandy soils, laterite soils, coastal alluvium and medium to deep black soils.

LAND USE AND AGRICULTURAL PRACTICES

12.11 State-wise land use details in the basin as in 1967–68, the latest year for which the statistics are available, are given in Table 12.4.

The culturable area in the basin is about 3.22% of the total culturable area of the country.

The total cropped area in the basin is about 3.16% of the cropped area in the country.

The area under irrigated crops is about 17% of the cropped area in the basin.

12.12 The general cropping pattern State-wise is described below:

Tamil Nadu

Of the gross irrigated area of 110,000 hectares rice accounts for 65.36% and sugarcane for 15%. Food crops are grown over 87.64% and non-food crops over 12.36% of the area. Cotton is grown over 6.36% of the area.

Kerala

80.42% of the gross irrigated area of 528,900 hectares in this State grows rice. Total food crops account for 90.91% and the non-food crops for 9.09%.

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*Evaporation Data (India), India Meteorological Department (April, 1970).

Table 12.4

Land Use Details

(*Thousand hectares*)

Item	Name of State							
	Tamil Nadu	Kerala	Mysore	Goa & Daman	Maharashtra	Dadra & Nagar Haveli	Gujarat	Total
1	2	3	4	5	6	7	8	9
Geographical area	470	3,593	2,510	367	3,257	49	966	11,218
Reporting area	470	3,538	2,492	367	3,194	48	639	10,742
Area under forests	137	976	1,114	105	618	21	201	3,172
Area not available for cultivation	60	301	231	34	608	3	60	1,297
Culturable area	273	2,261	1,147	228	1,968	24	378	6,279
Uncultivated culturable area	74	299	476	95	945	2	50	1,941
Net area sown	199	1,962	671	133	1,023	22	328	4,338
Area sown more than once	52	599	97	6	42	2	16	814
Total cropped area	251	2,561	768	139	1,065	24	344	5,152
Net area irrigated	69.9	380.0	132.9	8.0	35.1	—	34.8	660.7
Gross area irrigated	110.0	528.9	154.0	8.0	38.5		36.4	875.8
Percentage of net area sown to culturable area	72.89	86.78	58.50	58.33	51.98	91.67	86.77	69.09
Percentage of net area irrigated to culturable area	25.60	16.81	11.59	3.51	1.78		9.21	10.52
Percentage of net area irrigated to net sown area	35.13	19.37	19.81	6.02	3.43		10.61	15.23

Mysore

Of the gross irrigated area of 154,000 hectares the bulk of 75.52% grows rice and 5.19% sugarcane. Food crops are grown over 96.10% of the area and non-food crops over 3.90%.

Goa & Daman

Food crops are grown over the entire irrigated area of 8,000 hectares, rice, for 75% of the area.

Maharashtra

The gross irrigated area is about 38,500 hectares of which 20.78% is under rice, 6.49% under wheat and 15.06% under sugarcane. Food crops account for 78.18% and non-food crops 21.82% of which cotton is 1.03%.

Dadra & Nagar Haveli

Information is not available.

Gujarat

Of the gross irrigated area of about 36,400 hectares, 27.74% is under rice, 8.79% under wheat and 8.52% under sugarcane. 78.02% is under foodcrops and the remaining 21.98% is under non-food crops, out of which cotton alone accounts for 14%.

12.13 Summing up, of the total irrigated area of 875,800 hectares in the basin, about 72.80% is under rice and 2.80% under sugarcane. Food crops account for 90.40%. The remaining area *viz.* 9.60% is under non-food crops, of which cotton accounts for 1.60%.

REGIONAL ECONOMY

Population

12.14 On the basis of the 1971 census* and the percentage of the area of each district within the basin to the district as a whole, the total population in the basin is about 31.84 millions. The State-wise distribution is given on the page following.

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*Census paper 1 of 1971 (Supplementary), Registrar-General (India).

State	*Population* (million)
Tamil Nadu	2.02
Kerala	19.76
Mysore	3.76
Goa	0.79
Maharashtra	12.00
Dadra & Nagar Haveli	0.07
Daman	0.04
Gujarat	2.11
Total	40.55

There are nine cities in the basin which have a population of more than one lakh each. They are Greater Bombay and Thana in Maharashtra; Calicut, Cochin, Alleppey, Trivandrum and Quilon in Kerala; Mangalore in Mysore and Nagercoil in Tamil Nadu. The average density of the population in the basin is 362 persons per sq. km. The density varies from region to region within the basin. The most densely populated district of Greater Bombay in Maharashtra has 9,898 persons per sq. km. The next is Alleppey in Kerala with 1,124 persons per sq. km., while the district of Dangs in Gujarat has only 56 persons per sq. km. 76.6 per cent of the total population in the basin live in the rural areas and the balance of 23.4 per cent in urban areas. The working force constitutes about 34.78 per cent of the population. Nearly 34.16 per cent of the working force is engaged as cultivators, 27.57 per cent as agricultural labourers and the balance 38.27 per cent is employed on other activities.

Forests and agriculture

12.15 Forests and agriculture are the mainstay of the people. Nearly 29.51 per cent of the total area of the basin is covered by forests, the bulk of which are located in the States of Mysore and Kerala. The forests are mainly of the tropical monsoon variety. The area annually cropped in the basin is about 5.15 million hectares. Agriculture is generally rain-fed except for about 0.88 million hectares of irrigated area which mainly grows rice.

Power

12.16 The Central Water and Power Commission has conducted surveys to assess the hydroelectric potential of the country. The hydroelectric potential of the rivers from Trivandrum to Goa has been assessed as 4,345 M.W. at a 60% load factor. Information in respect of the other rivers of the basin lying in Maharashtra and Gujarat is not available. At present the demand for electrification of towns and industries etc. is mainly met by the following hydroelectric and thermal plants located in the basin:

Station	*Installed capacity* MW
Hydroelectric	
Existing	
Periyar	140
Sabarigiri (Pambakakki)	300
Sholayar	54
Pallivasal	37.5
Sengulam	48
Poringalkuthu	32
Neriamangalam	45
Penniar	30
Jog	120
Under Construction	
Kodaiyar	100
Parambikulam Aliyar	185
Iddiki	390
Kuttiyadi	75
Edamalayar	90
Sharavati Stage I	178
Stage II	534
Stage III	178
Kalinadi	309
Linganamakki	60
Vaitarna	60
Thermal	
Existing	
Chola	136
Trombay	337.50
Under Construction	
Cochin	55
Atomic	
Existing	
Tarapur	400

Mineral Wealth

12.17 The principal minerals found in the basin are*:

Iron ore: In the Shimoga and Chikmagalur districts of Mysore, the Kolaba and Ratnagiri districts of Maharashtra and the Coimbatore district of Tamil Nadu.

Manganese ore: In the Belgaum, Shimoga, North Kanara and Dharwar districts of Mysore.

Bauxite: In the Thana, Kolaba, Ratnagiri and Kolhapur districts of Maharashtra and the Belgaum district of Mysore.

Gypsum: In the Kolaba district of Maharashtra and the Coimbatore district of Tamil Nadu.

Ilmenite: In the Thana and Ratnagiri districts of Maharashtra, the Kanniyakumari district of Tamil Nadu and parts of Kerala.

Kyanite: In the Chikmagalur district of Mysore and parts of Kerala.

Ghaphite: In the Trivandrum district of Kerala.

Chromite: In the Ratnagiri district of Maharashtra and the Hassan district of Mysore.

Monazite: In parts of Kerala.

Limestone: In the Shimoga district of Mysore and the Palghat district of Kerala.

Some deposits of Corundum, Magnesite, Kaolin, Mica, etc., are also located in the various districts of Mysore lying in the basin.

Industries

12.18 There is a heavy concentration of industries, in Greater Bombay and the adjacent areas in Maharashtra. The important industries in the basin are:

Cotton Textiles: In Bombay, Cannanore, Trichur, Alwaye, Quilon and Trivandrum.

Sugar: In Bombay and Quilon.

Tobacco products: In Bombay, Ernakulam and Mangalore.

Vegetable oils: In Bombay and Ernakulam.

Cashewnut factories: In Ratnagiri, Mangalore, Calicut, Trichur, Ernakulam and Quilon.

Rubber and Rubber goods: In Bombay, Calicut, Cochin, Kottayam, Trivandram.

Plastic and allied products: In Bombay and Calicut.

Plywood and hard board etc.: In Bombay, Cannanore, Kottayam and Trivandrum.

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* Techno-Economic Surveys of Kerala, Maharashtra, Mysore and Tamil Nadu, NCAER.

Paper, newsprint, card board etc.: In Bombay and Ernakulam.

Cement: In Kottayam and Bombay.

Matches: In Bombay, Cannanore, Calicut and Tirvandrum.

Automobiles: In Bombay.

Ship-building: In Cochin.

Aircraft building and repair: In Bombay.

Agricultural equipment: In Bombay, Billimora, Coondapoor, Mangalore and Cochin.

Machine tools: In Bombay and Cochin.

Petroleum and its by-products: In Bombay.

Machinery and machine parts: In Bombay, Calicut, Trichur and Mangalore.

Fertilizers: In Bombay.

Chemicals: In Bombay and Alwaye.

Drugs and pharmaceuticals: In Bombay, Mangalore, Trivandrum, Quilon and Kottayam.

Communications

12.19 A major part of the basin is served by the Southern Railway. The northern part is served by the Central and Western Railway. The important lines are Mangalore-Cochin on the broad gauge, Cochin-Trivandrum and Cochin-Coimbatore on the metre gauge, Bombay-Kalyan-Poona, Bombay-Kalyan-Igatpuri and Bombay-Surat on the broad gauge. The basin is also served by portions of National Highways such as Bombay-Thana-Surat, Bombay-Thana-Nasik, Bombay-Thana-Poona, Calicut-Trichur-Nagercoil-Kanniyakumari, Trichur-Palghat-Coimbotore.

12.20 Most of the rivers in the basin are navigable in short stretches in the tidal reaches ranging from 6 to 64 km.* Kerala has a network of backwaters, artificial salt-water canals and tidal rivers which play a vital role in the communication system. The total length of these waterways is about 1,931 km. Before the construction of railways, much improvement was effected in the inland navigation system of Kerala by the construction of canals linking the backwaters and the tidal rivers. This system is known as the west Coast-system and is about 504 km. long. There are also several other canals and cross canals in Central Kerala connecting the towns in the mid-land and coastal region. These canals serve as feeders to navigable rivers and to the West Coast Canals system. The total length of the interior canals is about 563 km. At least 31 rivers in Kerala are navigable by different types of vessels including power-craft. Most are navigable during the monsoon up to their mid-land reaches and throughout the year in the tidal reaches. The total navigable length of these rivers (during the monsoon) is about 845 km. out of which about 177 km. can be used by small motor boats. Some of the important navigable rivers of Kerala are the Chandragiri, the Nileswar, the Karingote, the Kavvayi, the Kuppam, the Valapattanam, the Mahe, the Korapuzha the Kallayi, the Chaliyar (Beypore), the Kadalundi, the Tirur, the Bharatpuzha, the Periyar, the Muvattupuzha, the Meenachil, the Manimala and the Pamba.

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* Navigable Waterways of India, Central Water and Power Commission (1961).

The economy of the basin at present largely depends on agriculture, fisheries, and major industries which have developed in important towns all along the coast.

WATER RESOURCES

Surface water

12.21 The surface water potential of the west flowing rivers has been assessed at different times by different authorities. The first assessment was made by the Indian Irrigation Commission (1901–03) which estimated the anual run-off of this basin as 230,784 m. cu. m.* for a catchment area of 93,805 sq. km.

In 1949, when the basin-wise assessment of the water resources of the country was made on the basis of 'Khosla's empirical formula', the annual run-off of the west flowing rivers basin was estimated at 229,020 m. cu. m.†

In 1960, the C.W. & P.C. while conducting irrigation potential studies, assessed the total annual runoff of the basin as 217,894 m. cu. m.‡ based on the available observed data and Strange's co-efficients of rainfall and run-off.

Systematic gauge and discharge observations have been made on the rivers of the various States for sometime past. The observations are being conducted by the Gujarat State Government at eight stations, Mysore at five stations and by Tamil Nadu at two stations, as detailed on page 270. Information about Maharashtra is not available.

In Kerala, gauging stations have been established on various rivers and it is proposed to cover all the rivers in course of time. Discharge data for important rivers like the Bharatpuzha, Keecheri, Karuvannur, Chalakudy, Periyar, and Muverttupuzha has been recorded from 1963 onwards.

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*Report of the Indian Irrigation Commission (1901-03).

†An appraisal of Water resources by Dr. A. N. Khosla, UNESCO.

‡Report of the technological possibilities of irrigation projects in India, Central Water and Power Commission (Unpublished).

Station	River
1	2
Gujarat	
Ambika-aqueduct	Ambika
Sara	Ambika
Kali-Bell	Purna
Deli	Par
Nani-Vahial	Par
Rakholi	Damanganga
Nagar	Damanganga
Wapi	Damanganga
Mysore	
Dundeli	Kalinadi
Supa	Kalinadi (a tributary)
Causeway	Kalinadi (a tributary)
Gund	-do-
Kargal	Sharavati
Tamil Nadu	
Pechnipara	Kodaiyar
Perunchani	-do-

Rivers like the Chaliyar, Kuttiyadi, Valapattanam, Chandragiri, Kabbani, Meenachil, Pamba, Kallada have been covered from 1964 onwards.

The C.W. & P.C., under the programme of establishing and maintaining centrally sponsored key hydrological stations in the country, has proposed the establishment of the following seven gauge and discharge sites on the west flowing rivers.

Name of the river	Location of gauge and discharge site
1	2
Purna	Near Mehave
Vaitarna	Above its outfall
Mandvi	Above its outfall
Kalinadi	Below Kanari Confluence
Netravati	Near New Baitwal
Periyar	Road Bridge crossing
Periyar	Near Malayathur

The Commission has also recommended that the existing eight gauge/gauge and discharge sites on the following rivers may be maintained by the State Governments.

Name of the river	Location of gauge/gauge and discharge site
Damanganga	48 km before it joins the sea
Valapattanam	Near Kuilur
Beypore	16 km before it joins the sea
Bharatapuzha	Near Cheruchorti
Periyar	Iddikki H.E. Project
Pambiyar	Just above Ponachi
Achankovil	Near Pandalam
Kallada	24 km before it joins the sea

Ground Water

12.22 Systematic investigations and studies of the ground water potential of the basin have not been made so far. Only in some parts of the basin have some investigations and studies been done recently.*

Parts of the Kolaba and Thana districts of Maharashtra have been covered by systematic groundwater studies. The area is occupied chiefly by the lava flows of hard massive and soft vesicular types, and inter trappean beds. Wells piercing lava flows, tap groundwater from the weathered zones of massive traps and vesicular traps under watertable and confined conditions respectively.

In the Union Territory of Dadra and Nagar Haveli, Deccan traps occupy the entire area with a black soil cover of 0.5 to 1 m. thickness. Groundwater occurs under both water-table and confined conditions in the Deccan trap formations. There is good scope for groundwater development on a moderate scale by means of large diameter open wells and dug-cum-bore wells.

In Kerala, under the All India Exploratory Tubewells Project, exploratory drilling was carried out at 5 places in the districts of Quilon, Aleppey and Kottayam in 1958. The results indicated that the maximum thickness of sediments is 305 m. and that promising water bearing strata exist which are capable of yielding low to moderate quantities of water i.e. 45–67.5 kl./hr. by means of tubewells sunk to 180 m. Production zones within 120 m. can be developed between Mayyanad and Shertalai by means of medium duty tubewells and there is a progressive improvement in the quality of water from Shertalai to Karunagapalli, from saline to good potable water. Subsequent systematic studies in parts of these districts over an area of 800 sq. km. indicated that the Warkallai beds overlying Quilon beds and the Pleistocene and recent sediments are the most important formations for groundwater development in the west coast areas. The Warkallai beds consist of semi-consolidated sands, clays and sandstones and occur down to a maximum depth of 145 m. The Pleistocene and recent sediments overlying the Warkallai beds range in thickness from 7 m. to 35 m. and consist of alternating beds of sands, grey and black clays. Groundwater occurs in the Warkallai both under water-table and confined conditions. It occurs under water-table conditions in the laterite cappings over the Warkallai. Studies indicate that although the quality of groundwater varies considerably there is scope for the further development of groundwater in selected areas from the confined aquifers of the Warkallai beds.

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*Ground Water Resources of India, Status and Surveys, Prospects and Perspectives, Geological Survey of India (August, 1970).

In the Cochin area, data of 21 boreholes drilled ranging in depth from 6–197 m. for water supply to the Cochin port development area indicated that the chances of tapping groundwater by means of tubewells for irrigation and domestic purposes are not bright, because of the poor chemical quality of the water.

In Cannanore district, an area of 125 sq. km. in Hosdrug taluk has been covered by geohydrological surveys. Results indicate that groundwater occurs under water-table conditions in the sands and sandy soils which vary from a few metres to 29 m. in thickness. The sands are saturated below a depth of 2.5 to 3.0 m. b.g.l. down to 15 m. Open wells of 6 m. diameter to depths of 6–7 m. b.g.l. are likely to yield 110 kl/day and groundwater may be developed by shallow filter point wells when the sand is more than 12–15 m. thick.

In Palghat district, an area of 1000 sq. km. in Chittur Taluk underlain by granite gneisses and Charnokites and traversed by quartz veins and Pegmatite was covered by a systematic groundwater survey. The data indicates that the depths of open wells piercing the weathered rocks varied from 325 m. with depths to water table ranging from 2.5–18 m. b.g.1. These wells yield water in quantities above 35 kl/day in 3–5 hours pumping.

In Kozhikode district, geohydrological investigations over an area of 430 sq. km. in the Manjeri-Wanden area underlain by Biotite gneiss and Charnokites capped by laterite indicated that wells range in depth from 4–20 m. with the depths to water level in them ranging between 2.5 and 12 m. b.g.l. Limited scope for the development of groundwater by means of large diameter wells in gneissic rocks has been indicated. An area of 560 sq. km. in the Sultan's Battery area underlain by Dharwar rocks which was investigated for groundwater indicated that the depth to water in the open wells piercing Dharwar rocks ranged between 2 and 17 m. Large diameter open wells have been recommended for augmenting the water supply.

Further systematic exploratory work is necessary in the basin to make a scientific qualitative and quantitative assessment of the groundwater resources. When such an assessment is made, it will help to frame a rational plan of development for various needs.

EXISTING DEVELOPMENT

12.23 The only irrigation work undertaken in this basin prior to Independence was the Periyar Project across the river Periyar to utilise a portion of the abundant rainfall on the western slopes of the Ghats, for irrigation in the district of Madurai. The project was started in 1886 and completed in 1896 at a cost of Rs. 8.84 million. The headworks consist of a concrete dam erected below the junction of the Mullayar with the Periyar, with a maximum height above bed level of 48 m., top width 3.65 m. and a length of 378 m. The catchment is 781 sq. km. and the lake formed by the dam is 33 sq. km. in area. The water is led to the eastern side of the ridge by a tunnel 1981 m. long. About 76,893 hectares in Madurai district are being irrigated by this reservoir.

The first Indian Irrigation Commission after examining the working of the Periyar Project endorsed the possibility of extending the area under irrigation by 8,094 hectares by increasing the storage in the lake after erecting shutters on the waste-weir etc. It did not recommend any other specific project by name, to be taken up for construction in this basin.*

After 1947, various States in the basin (notably Kerala) as well as the Central Government laid great emphasis on irrigation and power development in the basin of the West Flowing Rivers. A number of works were taken up. The more important of these are: Chalakudy Stage-I, Mangalam, Malampuzha, Peechi, Walayar, Wadakancharry (Vazhani), Neyyar Stage-I, Neyyar Stage-II, Meenakara including Chillar (Gayathri) Stage-I & II and Pothundy in Kerala and Kodaiyar Extension and the Thiruparappa weir in Tamil Nadu, most of which were completed by 1969. Salient features of these schemes are given in the Appendices 12.1 and 12.2. Some of the important schemes are briefly described in the paragraphs below.

Malampuzha Project

The Malampuzha Project consists of a composite dam 38 m. high and 1849 m. long across the river Malampuzha—a tributary of the Bharatapuzha—in the Palghat district of Kerala State. It irrigates an area of 19,263 hectares of land. As two crops are grown over the entire area, the gross area annually irrigated is 38,526 hectares. Work on the project started in 1949, was completed in 1967. The cost of the project is Rs. 58.0 million and full benefits have been achieved.

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*Report of the Indian Irrigation Commission (1901-03).

Periyar Valley Project

The Periyar Valley Scheme consists of a barrage across the river Periyar at Palanchode in the Ernakulam district of Kerala State. The barrage will have a total length of 211 m. between the abutments. Canals take off from both banks to irrigate a net area of 25, 600 hectares, the gross area irrigated being 40,996 hectares. The work on the project started in 1956, and is expected to be completed during the Fourth Plan period. The cost of the project is esimated at Rs. 94.94 million.

Pamba Irrigation Project

The Pamba Irrigation Project, envisages a barrage across the Kakkad river—a tributary of Pamba—in Quilon district of Kerala State. The barrage will be 80 m. long and will have two canals—one on each bank to provide irrigation to a gross area of 34,000 hectares in Quilon and Alleppey districts. The cost of the project is estimated at Rs. 63.0 million. Started in 1956, it is expected to be completed by the end of Fourth Plan.

Kuttiyadi Irrigation Project

The project envisages a dam 171 m. long and 35 m. high across the Kuttiyadi river in the Kozhikode district of Kerala State. The dam which will be of masonry with earthen flanks will provide irrigation to a gross area of 31,162 hectares. The project costing Rs. 52.4 million, is expected to be completed during the Fourth Plan period.

Kallada Project

The work on the Kallada Project was started in 1962. It consists of a masonry dam 335 m. long and 73 m. high across the Kallada river in the Quilon district of Kerala State. The project, is by far the biggest irrigation scheme undertaken in Kerala and when completed, will provide irrigation to a gross area of 105,220 hectares. The project costing Rs. 144.91 million is expected to be completed during the Fifth Plan period (1974–79).

Chittarpattanamkal Project

The project envisages 2 earthen dams with interconnected channels across the Chittar tributaries of the Nodaiyar in Tamil Nadu. The first dam will have a length of 765 m. and be of the height 22 m. The second dam will be 1,076 m. long and 25 m. high. In addition the project envisages the following works:

(i) raising the F.R.L. of the existing Pechipara dam;
(ii) raising the F.R.L. of the existing Perichani dam;
(iii) a feeder channel from the reservoir on the Chittar Dam I to augment the supply of the left bank canal of the Kodaiyar system;
(iv) excavation of a new Pattanmkal Channel;
(v) extending and improving the channels taking off from Thiruparappa weir on the Kodaiyar river;
(vi) improvement of the Pandyankal Thoval and Nilpara canals in certain reaches, and the excavation of another channel taking off from the Nilpara channel of the Kodaiyar system;
(vii) improving and lining the left bank canal of the Kodaiyar system to take the additional flow diverted from the two Chittar Reservoirs.

The project costing Rs. 73.3 million is expected to be completed during the Fourth Plan period and will benefit an area of 19,020 hectares.

Parambikulam-Aliyar Project

12.24 This Project contemplates the integrated use of the waters of 7 west flowing rivers namely the Nirar, Sholayar, Parambikulam, Tunakadavu, Peruvaripallam, Aliyar and Palar. Of these rivers, the first five flow on the western side and the last two on the eastern side of the Western Ghats. The project envisages dams across all these rivers to form reservoirs. They will be inter-connected through tunnels. Ultimately, the water of these rivers will be diverted to the east to irrigate 97,130 hectares in the Coimbatore district of Tamil Nadu and 10,000 hectares in the Chittur area of Kerala. These rivers lie at various elevations ranging from +1,158 m. to +320 m. and the fall to lower elevations is proposed to be made use of to generate 185 MW of electricity. The details of the various structures of the Project are given page 276.

Some of the unique features are that the main canal, the distributaries and the minors up to 20 hectares limit are to be lined. Linning has been done practically throughout the distribution system. Field channels have been excavated by the Government up to the 10 hectares limit leaving

Salient feature	Nirar Weir	Sholayar dam	Parambikulam dam	Tunakadavu dam	Peruvari Pallam dam	Aliyar dam	Tirumurthi dam
1	2	3	4	5	6	7	8
Name of river	Nirar	Sholayar	Parambikulam	Tunakadavu	Peruvari Palam	Aliyar	Palar
Type of dam	Masonry weir	Masonry flanked by earth	Masonry with earth saddle dam	Earthen	Earthen	Masonry	Earthen
Length (Metres)	148	1184	318	338	945	3201	2680
Maximum height (Metres)	—	105	73	12	28	22	23
Benefits Irrigation	97,130 hectares						
Power	185 MW						
Cost	Rs.675.3 million						
Date of commencement			1959				
Date of completion				During Fourth Plan			

field chanels within 10 hectares to be excavated by the cultivators. This facilitates the speedy development of the ayacut. As lining has been done up to the 20 hectares limit the transmission losses of water have been restricted mainly to seepage through the irrigated fields. The construction of the project has been phased in such a way that even during the construction period irrigation facilities are being extended to the ayacut. Nearly 39,000 hectares were irrigated under the project up to the end of March, 1969.

Besides the major and medium projects in the basin, minor schemes comprising tanks, bandharas, wells, etc., irrigate a large area. The details of the area irrigated by the various sources like canals, tanks, wells etc. during the year 1967–68, state-wise in this basin are given in Table 12.5.

Table 12.5

Area Irrigated in the Basin—Sourcewise

Sl. No.	Source of Irrigation	Area irrigated (hectares)							Total
		Tamil Nadu	Kerala	Mysore	Goa & Daman	Maharashtra	Dadra & Nagar Haveli	Gujarat	
1	2	3	4	5	6	7	8	9	10
1.	Canals	34.2	178.5	21.2	—	10.4	—	24.4	268.7
2.	Tanks	12.0	65.6	38.4	—	0.8	—	1.9	118.7
3.	Open Wells	22.4	5.5	15.1	—	16.2	—	8.2	67.4
4.	Other sources	1.3	130.4	58.2	—	7.2	—	0.3	197.4
	Total	69.9	380.0	132.9	—	34.6	—	34.8	652.2

On completion and full development the major and medium projects under operation and construction in the basin in 1968–69 will use about 7,538 m. cu. m. of water inclusive of the reservoir losses.

In the absence of any statistics for minor schemes, the utilisation by such projects has been estimated by the Commission on the basis of the total area irrigated under these sources. The approximate utilisation by the minor projects including tank losses at the beginning of the Fourth Plan works out to 5,929 m. cu. m.

The total utilisation by the major, medium and minor projects undertaken up to the beginning of the Fourth Plan, on their completion and full development is of the order of 13,467 m. cu. m. of which 12,661 m. cu. m. are from surface waters and 806 m. cu. m. from groundwater.

The data on industrial needs in the basin are not readily available. So far, no problem of water pollution by industrial waste has been reported.

FUTURE DEVELOPMENT

12.25 No new major or medium project in this basin has so far been approved for inclusion in the Fourth Five Year Plan. However, the States have proposed certain projects to be taken up for construction in the Fourth Five Year Plan subject to clearance from the Planning Commission.

Gujarat has proposed the Damanganga project. This is a multipurpose project which besides benefiting portions of Bulsar district will benefit the enclaves of Dadra and Nagar Haveli. It will irrigate an area of 45,200 hectares.

Maharashtra has stated that because of the ruggedness of much of the terrain and steep gradient there is not much scope for the future development of projects in this basin. However, the State has proposed the Amba Valley project estimated to cost Rs. 12.50 million to benefit 9,980 hectares.

Kerala has proposed the following 8 projects.

Appendix 12.3 shows the salient features of the above projects. These projects are likely to utilise 3,311 m. cu. m. benefiting 269,970 hectares.

By the end of the Fourth Five Year Plan, the area under minor schemes is expected to increase by about 210,090 hectares requiring nearly 2,833 m. cu. m. of water, including reservoir losses.

Thus the additional utilisation by the Fourth Plan major, medium and minor projects would be of the order of 6,144 m. cu. m. of water benefiting an area of about 0.48 million hectares.

On the full development of the Fourth Plan projects, a total quantity of 19,611 m. cu. m. of water (18,420 m. cu. m. of surface water +1,191

Name of project	Benefits (hectares)	Estimated cost (Rs. million)
1	2	3
Karapuzha	10,520	20.0
Chimoni	16,190	25.0
Kuriarkutty	34,820	50.0
Kakkadavu	20,234	50.0
Silent Valley	32,400	35.0
Idikki	97,130	112.5
Vamanapuram	23,470	51.0
Mupli	24,300	20.0
Total	259,064	369.50

m. cu. m. of ground water) would have been used for irrigating a total area of about 1.58 million hectares.

FLOODS, WATERLOGGING AND DRAINAGE

12.26 Floods are a problem in those parts of the basin located in Gujarat, Mysore and Tamil Nadu.

In Maharashtra area the flood problem mainly affects the towns situated at the mouths of rivers. The river beds tend to get silted up over a period of years. As a result, the high flood level is raised and the town situated on the banks are periodically inundated. The problem is most pronounced when high floods in the rivers synchronise with high tides.

Floods are a common feature in Kerala and are very severe in certain years causing considerable loss to property and human life. The State is traversed by numerous streams, and during the heavy monsoon, these streams flow in torrents which overtop the banks and flood the low lying areas. The problem of floods is particularly severe in the mid-lands and in the coastal reaches. During the First Plan, little effort was made to combat floods. However during the Second Plan period, a Flood Control Board was constituted to devise measures for controlling floods. Among the steps recommended by the Board were the construction of flood banks, and the widening and deepening of rivers. During the Third Plan, Rs. 6.1 million were spent on flood control works and an area of about 4,300 hectares was protected from floods. The State Government propossed to take up during the Fourth Plan works like, the Improvement of the Champakara throde, the opening of the Irumbanam-Puthussery-Nadamil Canal and the Keeranallur-Pooraparamba Canal.

In Kerala, as has already been stated, almost all the rivers which are low in the coastal region are tidal and connected by tidal backwaters and lagoons. During the rainy season, fresh water flowing down the rivers keeps out the salt water in the tidal reaches. After the rainy season when the flows in the rivers dwindle, the saline water from the sea enters the lakes and travels as far as 25 km. inland contaminating the water courses and making them unfit for irrigation or for domestic use. It covers low-lying fields and percolates by capillary action into the adjacent high lands. Where the low-lying lands are enclosed within clay bunds the saline intrusion takes place by seepage or by breaching of the bunds. The area which suffers most due to the intrusion of salinity also has the heaviest concentration of population, and is the most intensively cultivated area in the State. The most effective method of dealing with salt water intrusion is by conserving the entire run-off from the rivers during the rains and releasing it in a steady and continuous flow after the rains. However this is not possible in many of the rivers because of a lack of storage facilities. Regulators or barriers across streams at suitable sites can prevent the intrusion of salt water to a considerable extent. However any device which completely excludes the entry of salt water into the backwaters or lakes would adversely affect the coir-industry in the coastal region. Bearing this in mind, salt exclusion works of the bed regulator type in the various river basins and backwaters are suggested. When shutters are lifted, the waterway remains unaffected as far as the flood flow is concerned, while by the closure of the shutters, the movement of tidal water and saline intrusions will be prevented. One of the longest of the salt exclusion schemes of this kind in Kerala is the Thannermukkam Regulator across the Vembanad lake, costing Rs. 15 million and benefiting 50,000 hectares. The master plan for salinity control in Kerala contains as many as 13 schemes costing Rs. 40 million and benefiting 25,000 hectares.

12.27 Drainage is a major problem only in the coastal region. Thousands of acres of land are cultivated immediately after the commencement of the South-west monsoon. They are divided into blocks not exceeding a few hundred hectares enclosed within clay bunds formed at considerable cost and dewatered by specially designed pumps. Reduction of flood levels will make it easier for the ryots to maintain these bunds and to strengthen them sufficiently to withstand floods. It will also be possible to dewater the blocks even during the monsoon and to raise an additional crop. The largest scheme of this kind is in Kuttanad.

GENERAL

12.28 The entire length of 580 km. of the sea coast in Kerala is exposed to sea erosion. At certain places like Manassery near Cochin, the sea advances by about 30 m. to 45 m. during the monsoon months and recedes by 25 m. to 35 m. resulting in a loss of 5 to 10 m. of land every year. Many attempts in previous years to prevent the encroachment of the sea were not effective. Methods of protection were studied at the CWP Research Station, Poona. These studies have revealed that the only permanent method is the construction of a sea wall and groynes. In the First Plan experimental work for the prevention of sea erosion along 1.6 km. of the worst affected area of the coast was taken up. During the Second Plan, long sea walls were constructed to protect about 25 km. of sea coast. In the Third Plan 58 km. of sea coast was protected by sea wall. To ensure the complete protection of the affected coastal stretches about 320 km. of sea wall will have to be put up.

12.29 The number and distribution of rain-gauge stations should be reviewed and new stations to fill any such gaps as exist should be established. It is also important that the daily rainfall data for all these stations should be published on a monthly basis.

12.30 A network of evaporation measuring stations in the basin, particularly at the sites of the existing and proposed reservoirs needs to be established.

12.31 Gauge and discharge observations should be made on the various river systems in the basin. Many of the rivers in the basin are not being gauged at present. The observations should be continued in a scientific way on a permanent basis to obtain data essential not only for the preparation of the individual projects but also for the regulation of the individual projects and also for the regulation of available river water.

12.32 Systematic and scientific exploratory work is needed for a quantitative and qualitative assessment of the ground water resources in the basin so that these can be exploited in a rational way either independently or in conjunction with the surface water.

12.33 Systematic data in respect of the sediment carried by the rivers needs to be collected.

SALIENT FEATURES OF THE TAPI BASIN

(i) Source: Near Multai in Betul District of Madhya Pradesh (Latitude 21°43′N, Longitude 78°16′E).

			Km.	Miles
(ii)	Length	Madhya Pradesh	228	142
		Common boundary between Madhya Pradesh and Maharashtra	54	33
		Maharashtra	228	142
		Gujarat	214	133
		Total	724	450

			sq. km.	sq. miles
(iii)	Drainage area	Madhya Pradesh	9,804	3,785
		Maharashtra	51,504	19,886
		Gujarat	3,837	1,481
		Total	65,145	25,152

(iv) Population (1971 Census) 8.75 millions

(v) Density of Population 134 per sq. km. 347 per sq. mile.

(vi) Maximum discharge: At Hope Bridge in Surat in Aug, 1944 27,308 cumecs 964,320 cusecs

(vii) Minimum discharge N.A

			m.cu.m.	MAF
(viii)	Annual runoff			
	(a) at 90% dependability		8,963	7.27
	(b) at 75% ,,		13,235	10.73
	(c) at 50% ,,		17,982	14.58
(ix)	Maximum annual run-off recorded todate:	At Kathore in 1944	39,743	32.22
(x)	Minimum annual runoff recorded todate:	At Kathore in 1920 (Extrapolated from observed data)	4,095	3.22

		Thousand hectares	Thousand acres
(xi)	Culturable area (1967-68)	4,417	10,606
(xii)	Net area sown (1967-68)	3,800	9,390
(xiii)	Gross area sown (1967-68)	3,966	9,800
(xiv)	Net area irrigated (1967-68)	178	440
(xv)	Gross area irrigated (1967-68)	235	581
(xvi)	Area irrigated after completion and full development of Fourth Plan projects	890	2,199

(xvii) Probable additional irrigation by future projects N.A.

(xviii) Water utilisation including reservoir losses

		m.cu.m.	MAF
(a) On completion & full development of major, medium and minor projects under operation and construction in 1968-69	Surface water	5,383	4.36
	Ground water	1,545	1.25
	Total	6,928	5.61
(b) On completion and full development of Fourth Plan projects:	Surface water	6,161	4.99
	Ground water	2,654	2.15
	Total	8,815	7.14

SALIENT FEATURES OF THE KIM BASIN

(i) Source: South-west of village Koyalimandvi in the Broach District (Latitude 21°32′N, Longitude 73°20′E).

(ii)	Length	97 km.	60 miles.
(iii)	Drainage area	2,779 sq. km.	687 sq.miles
(iv)	Population (1971 Census)	0.39 million.	
		per sq. km.	per sq. mile
(v)	Density of Population	219	567
(vi)	Average annual run-off of the basin	N.A.	
		Thousand hectares	Thousand acres
(vii)	Culturable area (1967-68)	119	294
(viii)	Net area sown (1967-68)	106	262
(ix)	Gross area sown (1967-68)	111	274
(x)	Net irrigated area (1967-68)	10.1	25
(xi)	Gross irrigated area (1967-68)	10.5	26

			m. cu. m.	MAF
(xii)	Water utilisation including reservoir losses from projects under operation and construction in 1968-69	Surface water	65.0	0.05
		Ground water	44.0	0.04
		Total	109.0	0.09

CHAPTER XIII

THE TAPI BASIN

The Tapi basin extends over an area of 65,145 sq. km., and lies between east longitudes 72°38′ to 78°17′ and north latitudes 20°5′ to 22°3′. Situated in the Deccan plateau, the basin covers large areas in the States of Madhya Pradesh, Maharashtra and Gujarat. The State-wise distribution of the drainage area is shown below:

Table 13.1

Drainage Area in the Tapi Basin—State-wise

Name of State	Drainage area
1	2
Madhya Pradesh	9,804 sq. km.
Maharashtra	51,504 sq. km.
Gujarat	3,837 sq. km.
Total	65,145 sq. km.

13.2 The Tapi basin is bounded on the north by the Satpura range, on the east by the Mahadeo hills, on the south by the Ajanta range and the Satmala hills and on the west by the Arabian Sea. The Gawilgarh hills form the dividing line between the Upper Tapi and the Purna sub-basins. The basin has an elongated shape with a maximum length of 587 km. from east to west and a maximum width of 201 km. from north to south.

It has two well-defined physical regions, viz. the hilly region and the plains. The hilly region covers the Satpuras, the Satmalas, the Ajanta and the Gawilgarh hills and is well forested. The Khandesh and the Gujarat plains are broad and fertile areas suitable for cultivation.

THE RIVER SYSTEM

13.3 The Tapi which is the second largest west-flowing inland river of the Peninsula, rises near Multai in the Betul District of Madhya Pradesh State, at an elevation of 752 m. in comparatively open country. In the head reach covering a distance of about 241 km., the river traverses an open and partially cultivated plain before plunging into a rocky gorge in the Satpura hills. The valley is narrow up to Burhanpur, whereafter it widens.

In the next reach of 290 km., the river enters the Khandesh District of Maharashtra. Shortly after it receives the Purna, a major tributary from the left and then flows through the broad and fertile Khandesh plains, which are bounded on the north by the Satpuras and on the south by the Ajanta range.

In the next reach of about 80 km., it passes through wild and almost uninhabited country. The Satpura hills on the north and the Satmalas on the south close in. There are a series of rapids for a distance of about 32 km. between Kakrapar and Kamalpur. Through the Kakrapar rapids, the river falls, by nearly 4.6 m.

In the last reach of 113 km., the river passes through the Gujarat plains and after flowing past Surat city empties into the Arabian Sea. The tidal influence is felt up to 48 km. from its mouth in the Gulf of Cambay.

The total length of the river from the head to its outfall into the sea is 724 km., of which 228 km. are in Madhya Pradesh, 228 km. in Maharashtra, 214 km. in Gujarat and the remaining 54 km. form the common boundary between Madhya Pradesh and Maharashtra.

13.4 The Tapi receives several tributaries on both banks. The Bhokar, the Suki, the Mor, the Harki, the Manki, the Guli, the Aner, the Arunavati, the Gomai, the Gomati and the Valer join it from the right, and the Purna, the Bhogvati, the Vaghur, the Girna, the Bori, the Panjhra, the Buray, the Amarvati, the Shiva, the Rengavati and the Nesu join from the left.

The right bank tributaries have their origin in the Satpura range and flow generally south-west. The left bank tributaries, except the Vaghur, originate from the eastern slopes of the Sahyadris and the Galna hills, which are spurs of the Western Ghats, and flow eastward for considerable distances at right angles to the main line of the Ghats before changing their direction of flow northwards to join the Tapi. The more important tributaries of the Tapi are described briefly in the following paragraphs.

The Purna is the principal affluent of the Tapi. It is the main artery of a network of rivers and streams draining the Akola, the Amaravati and the Buldana districts of Maharashtra and the Betul district of Madhya Pradesh. It is the only river in the upper basin, which has a perennial flow. Rising in the Gawilgarh hills at an elevation of 900 m., at north latitude 21°38′ and east longitude 77°36′, the Purna flows first in a south-westerly direction for about 60 km. through hills and forests, whereafter it enters the Purna plains. Flowing in a generally westerly direction for a total length of 274 km., the Purna joins the Tapi north-west of Edalabad. The Pedhi, the Katpurna, the Murna, the Mun and the Nalganga are the main left bank tributaries of the Purna, and the Arna, the Chandrabhaga and the Wan are the principal right bank tributaries. The Purna drains a total area of 18,929 sq. km.

The Vaghur rises in the Ajanta hills at an elevation of about 751 m. at north latitude 20°29′ and east longitude 75°42′ and flows in a generally northerly direction for a total distance of 96 km. to join the Tapi on the left, north-west of Bhusawal. The Vaghur drains a total area of 2,592 sq. km.

The Girna rises in Western Ghats at an elevation of 900 m. at north latitude 20°44′ and east longitude 73°51′. It flows first in an easterly direction up to Jamda and then turns north. It takes a westerly turn at Nandra to join the Tapi from the left near Nanded. The river flows for a total distance of 260 km. and drains a total area of 10,061 sq. km., which is nearly one-sixth of the total catchment of the Tapi. The waters of the Girna are used for irrigation in Nasik and Jalgaon districts.

The Bori rises in the Malegaon sub-division of Nasik district at north latitude 20°48′ and east longitude 74°22′, at an elevation of about 600 m. and flows first in an easterly direction and then in a northerly direction to join the Tapi from the left, east of Betavad. The Bori flows for a total length of 130 km. and drains an area of 2,580 sq. km. The waters of the Bori are much used for irrigation in Dhulia and Jalgaon districts.

The Panjhra rises near Pimpalner from the crest of the Sahyadri hills at an elevation of 600 m., at north latitude 20°52′ and east longitude 73°55′ and after flowing east for about 99 km., it takes a turn to the north and joins the Tapi from the left, south of Thalner. The river flows for a total distance of 138 km. and drains an area of 3,257 sq. km.

The Buray rises in the Satmala hills at an elevation of 600 m., at north latitude 21°10′ and east longitude 74°4′ and flows in a generally easterly direction for a total distance of 64 km. and then turns north-east and flows for another 23 km., to join the Tapi from the left, north-east of Sindkheda. The river drains a total area of 1,419 sq. km.

The Aner is the longest right bank tributary of the Tapi. It rises at an elevation of 600 m. at north latitude 21°23′ and east longitude 75°45′ from the southern slopes of the Satpura hills and flows in a generally south-westerly direction for a total length of 94 km., to join the Tapi from the right, south of Hol. The river drains a total area of 1,702 sq. km.

The Arunavati rises at an elevation of 450 m., at north latitude 21°33′ and east longitude 75°11′ from the southern slopes of the Satpura hills and flows in a generally south-westerly direction for a total length of 53 km. to join the Tapi from the left, east of village Virdel. It drains a total area of 935 sq. km.

The Gomai also rises from the southern slopes of the Satpura hills at an elevation of 600 m., at north latitude 21°47′ and east longitude 74°46′ and flows in a generally south-westerly direction for a total length of 58 km., to join the Tapi from the right near village Prakasha. It drains a total area of 1,148 sq. km.

CLIMATE

13.5 There are four distinct seasons in the basin. They are (i) cold weather, (ii) hot weather, (iii) south-west monsoon and (iv) post-monsoon.

The cold weather season commences in December and continues till the end of February. December is the coldest month. The season is characterised by bright cloudless days and nights. Frost and hail are unknown. There is slight precipitation in the upper reaches of the basin during this season.

The hot weather starts in March and continues up to the middle of June. May is usually the hottest month. This season is generally dry except for occasional thunder-storms.

The south-west monsoon sets in by the middle of June and withdraws by the first week of October. June to September is the period of heaviest rain. During this season, the weather is somewhat sultry and oppressive, especially in areas adjoining the Tapi river.

In the post-monsoon season, a few thunder-storms occur, especially in October. Thereafter, the weather clears up and it is dry and pleasant throughout the valley.

Rainfall

13.6 There are at present 78 rain-gauge stations inside the basin. They are evenly distributed and adequate in number. The data from the stations are collected and printed by the appropriate authorities in the respective States and appear in the annual volumes showing the daily rainfall of India issued by the India Meteorological Department. In addition to the reporting rain-gauge stations, there are also a number of non-reporting rain-gauges. The data for these non-reporting stations are not issued by the India Meteorological Department. The India Meteorological Department has published the normal monthly and annual rainfalls of all the reporting rain-gauge stations in the basin for the period 1901–1950. The monthly and annual normals of rainfall in the district lying in the basin are given in Table 13.2.

The normal rainfall near the sea in the region is 1,000 mm. If we draw a line from Surat which is near the sea to Atnar in the extreme east, we find that there are two peaks of rainfall, one of 1,565 mm. at Songarh and another of 1,500 mm. near Chikalda. Between Songarh and Burhanpur, there are two troughs, one of 500 mm. and another of 800 mm. Near Atnar, the rainfall is 1,000 mm.

The normal annual rainfall in the Tapi basin up to Kathore is 830 mm., about 90% of which is received during the monsoon months. The monthly distribution of the normal rainfall over the entire basin is shown below:

Table 13.2

Monthly Normal Rainfall

Months	Rainfall (mm.)	Percentage of annual rainfall
1	2	3
June	136.1	16.4
July	252.9	30.5
August	168.4	20.3
September	160.9	19.4
October	43.2	5.2
Dry months	68.3	8.2

Although the monsoon withdraws during the first week of October, 5.2% of the annual rainfall is received during this month and in the wake of a wet September, this amount of rainfall is likely to produce a comparatively higher runoff and, for this reason, the month of October has been included in the monsoon months.

Temperature

13.7 In the cold weather season, the mean minimum temperature varies from 11.1°C to 14.4°C. Temperatures below freezing point have also been observed in several areas. Malegaon for example recorded 0.6°C in 1929.

In May which is the hottest month of the hot weather season, the mean maximum temperature ranges from 38°C to 42°C. Temperatures rise as we go inland from the coast and from the hills towards the plains. The Purna sub-basin in the upper half of the Tapi basin is one of the

Table 13.3

Monthly and Annual Rainfall in the Tapi Basin

State/District	Month-wise Normal Rainfall in mm.												Annual normal rainfall in mm
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Madhya Pradesh													
1. Betul	17.7	17.1	15.6	8.0	13.1	154.7	336.4	258.7	175.5	50.5	28.5	8.1	1,083.9
2. Hoshangabad	14.1	9.4	7.2	2.5	9.9	156.2	439.5	361.7	230.3	34.0	21.3	8.4	1,294.5
3. East Nimar	8.8	5.3	4.0	1.5	9.3	138.2	282.6	196.6	168.7	33.9	23.0	8.1	880.0
4. West Nimar	2.5	1.7	2.9	1.7	8.4	133.1	265.3	183.8	170.5	37.1	19.4	5.1	831.5
Maharashtra													
5. Akola	10.6	12.0	8.4	7.4	11.2	147.9	247.5	169.1	157.7	39.0	26.1	9.6	846.5
6. Amaravati	12.6	15.9	8.6	6.5	12.2	150.1	258.3	182.0	157.0	43.1	22.6	8.4	877.3
7. Aurangabad	7.4	4.3	4.1	5.8	16.8	134.1	173.5	122.7	170.2	47.0	31.0	8.9	725.8
8. Buldana	9.7	9.3	6.6	6.8	11.6	150.0	219.1	147.6	157.4	45.3	27.8	11.6	802.8
9. Dhulia	6.1	2.0	1.9	2.0	8.5	120.4	211.2	133.3	131.1	34.7	17.3	5.5	674.0
10. Jalgaon	7.6	3.5	3.7	2.2	12.1	132.1	209.9	149.4	151.3	38.9	23.0	7.0	740.7
11. Nasik	4.1	1.9	1.6	5.5	19.2	154.1	339.9	221.4	180.0	60.9	28.8	4.6	1,022.0
Gujarat													
12. Broach	3.2	1.6	0.8	3.5	4.2	137.6	368.4	209.5	176.5	32.5	10.6	1.3	949.7
13. Surat	3.2	2.0	0.9	2.5	6.7	240.9	634.1	344.8	229.6	42.4	12.3	1.8	1,521.2

Source: Memoirs of the India Meteorological Department, Vol. XXXI, Part III.

hottest regions in India during the summer. During the day the heat is severe but after sun-set the temperature drops considerably, and the nights are cooler. Dust storms are common in the western area and over a part of Khandesh district. Unlike the upper half of the Tapi basin, in the Khandesh area the burning hot winds blow far into the night. In the coastal regions, the north-easterly winds which grow hotter with the advance of the summer, blow in the early part of the day changing to a sea breeze from the west in the afternoon. The maximum temperatures recorded at different places in the basin are shown below:

Table 13.4

Maximum Temperature in Narmada Basin

Place	Maximum temperature recorded
1	2
Surat	45.6°C
Akola	47.2°C
Amaravati	46.7°C
Malegaon	43.3°C

During the south-west monsoon period, the mean temperatures in the basin vary from 25°C to 30°C.

Evaporation

13.8 The data on evaporation is not available. Though there are no departmental observatories of the India Meteorological Department within the basin, there are three agro-meteorological observatories of that department located at Surat, Jalgaon and Akola.* The evaporation losses assumed in the various reservoir projects in the basin are given in Table 13.5.

From the figures shown in this table it would appear that the assumed evaporation rates are less than those indicated by the general meteorological conditions at the site.

SOILS

13.9 No systematic soil survey of the Tapi basin has been carried out so far. Reconnaissance soil surveys have been done by the Central Water & Power Commission in connection with the Ukai and Kakrapar projects. These surveys and the general data regarding the soils of India

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*Evaporation Data (India), India Meteorological Department, (April, 1970).

Table 13.5

Monthly Evaporation Losses Assumed in the Tapi Basin

Sl. No.	Name of the Project	Evaporation (cm.)												
		Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.	Ukai*	13	13	20	23	26	20	10	10	15	20	15	13	198
			Hot Weather				Kharif				Rabi			
2.	Upper Tapi**		122				76				46			244

*Ukai Project, Government of Gujarat (1955).

**Upper Tapi Project, Government of Maharashtra (1966).

indicate that the Tapi basin consists mainly of black soils. The coastal plains in Gujarat are composed of alluvial clays with a layer of black soil in the surface.

The basin partly covers the districts of Betul, Hoshangabad, East Nimar and West Nimar in Madhya Pradesh; Akola, Amaravati, Aurangabad, Buldana, Dhulia, Jalgaon and Nasik in Maharashtra and Broach and Surat* in Gujarat State. The principal soil types found in the various district lying in the basin are described below: †

Table 13.6

Soils in the Tapi Basin—District-wise

District	Type of soil
1	2
Betul	Shallow black
Hoshangabad	Medium and deep black
East Nimar	Medium black
West Nimar	-do-
Akola	-do-
Amaravati	-do-
Buldana	Deep black
Dhulia	Medium and deep black
Jalgaon	-do-
Nasik	Medium black
Broach	Black and coastal alluvium
Surat	Medium black, deep black

LAND USE AND AGRICULTURAL PRACTICES

13.10 State-wise land use details in the basin in 1967–68 the latest year for which the statistics are available, are given in Table 13.7.

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*Prior to formation of Bulsar district.

†Soils of India by S. P. Raychaudhari, R. R. Aggarwal, N. R. Datta Biswas, S. P. Gupta and P. K. Thomas.

Table 13.7

Land Use Details in Tapi Basin

(Thousand hectares)

Item	Name of State			
	Madhya Pradesh	Maharashtra	Gujarat	Total
1	2	3	4	5
Gross area	980	5,150	384	6,514
Reporting area	980	5,136	243	6,363
Area under forests	403	1,189	55	1,647
Area not available for cultivation	62	339	23	424
Culturable area	515	3,608	169	4,292
Uncultivated culturable area	128	344	20	492
Net area sown	387	3,264	149	3,800
Area sown more than once	18	142	6	166
Total cropped area	405	3,406	155	3,966
Net area irrigated	17	144	17	178
Gross area irrigated	18	199	18	235
Percentage of net area sown to culturable area	74.9	90.5	88.2	88.5
Percentage of net area irrigated to culturable area	3.3	4.0	10.1	4.2
Percentage of net area irrigated to net sown area	4.4	4.4	11.4	4.7

The culturable area in the basin is about 2.2% of the total culturable area of India. The total cropped area in the basin forms 2.4% of the total cropped area in the country. The area under irrigated crops is about 5.9% of the cropped area in the basin. The general cropping pattern, State-wise is described below:

Madhya Pradesh

Of the gross irrigated area of nearly 17,300 hectares, 58.4% is under wheat, 6.4% under sugarcane, 9.8% under gram and the rest under other crops. The other irrigated crops are jowar, maize, barley, tur, fruits, vegetables, linseed, tobacco and fodder crops. Food and non-food crops cover about 98.3% and 1.7% of the irrigated cropped area respectively.

Maharashtra

Of the gross irrigated area of 199,900 hectares, 35.0% is under wheat, 3.7% under sugarcane, 5.7% under rice, 3.9% under gram and the rest under other crops. The other irrigated crops are jowar, maize, condiments, spices, groundnut, tobacco, fodder crops, etc. Food and non-food crops cover about 89.8% and 10.2% of the irrigated cropped area respectively.

Gujarat

Of the gross irrigated area of 17,700 hectares, about 24.9% is under rice, 8.5% under wheat, 22.0% under cotton, 7.3% under sugarcane and the rest under other crops. The other irrigated crops are jowar, bajra, condiments, spices, groundnut and fodder crops. Food and non-food crops cover about 71.8% and 28.2% respectively.

Summing up, of the total irrigated area in the basin, 34.7% is under wheat, 7.1% under cotton, 4.2% under sugarcane, 6.7% under rice, 4.1% under gram and the rest under miscellaneous crops. Food and non-food crops cover about 89% and 11% respectively.

From the agricultural point of view, the seasons are the kharif or monsoon (15th June to 14th October), the rabi or cold weather (15th October to 14th February). Wherever irrigation facilities exist, perennial and eight-month crops are cultivated. Cultivation is done mostly by a system of rotation of crops. The crops are grown chiefly in the kharif and rabi seasons.

13.11 The sowing and harvesting seasons of the principal crops in the various States are given in Table 13.6.

REGIONAL ECONOMY

Population

13.12 On the basis of the 1971 census* and the percentages of the area of each district within the basin to the district as a whole, the total population in the basin is about 8.75 millions. The State-wise distribution is shown in Table 13.7.

There are three cities in the basin, which have a population of more than one lakh. They are Malegaon and Akola in Maharashtra and Surat in Gujarat. The average density of population in the basin is 134 persons per sq. km. against the figure of 182 for India as a whole. The density varies from region to region. The most densely populated district of Surat has 230 persons per sq. km. while the district of Betul has 73

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*Census Paper I of 1971 (Supplementary), Registrar-General (India).

Table 13.8

Sowing and Harvesting Seasons of Principal Crops in the Tapi Basin

Name of crop	Period of	
	Sowing	Harvesting
1	2	3
Madhya Pradesh		
Wheat	October-November	February-April
Gram	October	February
Barley	October	February-March
Jowar (Kharif)	June-July	November-January
Jowar (Rabi)	October	March
Bajra	June	December
Maize	June	September
Ragi	June-July	September-November
Sugarcane	December-January	November-March
Cotton	June-July	November-Feburary
Maharashtra		
Wheat	October-November	February-April
Gram	September-November	January-April
Jowar (Kharif)	June-July	November-January
Jowar (Rabi)	September-October	January-March
Bajra	June-July	October-November
Ragi	June-July	October-November
Tur (Kharif)	June-July	February-March
Sugarcane	June-July (A) January-March (E)	October-December (A) December-February (E)
Cotton	June-September	November-March
Gujarat		
Rice (Autumn)	June-July	October-November
Jowar (Kharif)	July-August	January-February
Jowar (Rabi)	September-October	February
Bajra	June-July	October
Maize	June-July	October
Tur (Kharif)	June-July	February-March
Sugarcane	October-January	December-March
Cotton	June-July	January-February

A=Adhsali E= Eksali

Source : Indian Crop Calendar, Directorate of Economics & Statistics, Ministry of Food & Agriculture, C.D. & Cooperation (1967).

Table 13.9

Population in the Tapi Basin

State	Population
1	2
Madhya Pradesh	0.79 millions
Maharashtra	7.42 „
Gujarat	0.54 „
Total	8.75 millions

persons per sq. km. Out of the total population in the basin, 78.3% live in rural areas while the balance of 21.7% live in urban areas. The working force constitutes nearly 28.4% of the total population. 53.1% of the working force is engaged as cultivators and 32.3% as agricultural labourers. The balance of 14.6% of the working force is employed in manufacturing and other tertiary activities.

Forests and Agriculture

13.13 In the basin, forests occupy 25.4% of the total area and the culturable area constitutes 68.1%. Out of the total culturable area of 4.59 million hectares, nearly 3.99 million hectares are annually cultivated. An area of 0.17 million hectares constituting 4.3% of the cultivated area is irrigated annually. Wheat is the most important irrigated crop in the basin covering nearly 30.3% of the total irrigated area.

Power

13.14 The hydroelectric power potential of the basin has been assessed by the Central Water and Power Commission as 90 MW at 60% load factor. At present, there are no major hydroelectric stations in the basin. The Ukai multipurpose project, which will have an installed capacity of 300 MW, is under construction. There are four thermal stations in the basin at Utran, Bhusawal, Chandni and Paras. A major thermal station at Ukai, which will have an installed capacity of 480 MW is under construction. The details of the power projects under operation and construction are given in Table 13.10.

Table 13.10

Power Projects in the Tapi Basin

Name of the station	Installed capacity in M.W.	
	Hydro	Thermal
1	2	3
Ukai Multipurpose Project	300	—
Utran	—	67.5
Bhusawal	—	62.5
Chandni	—	27.0
Paras	—	92.5
Ukai Thermal Scheme	—	480.0
Total	300	729.5

The power generated is fed into the State grids.

Mineral Wealth

13.15 The principal minerals found in the basin are coal and graphite in Betul, and Manganese in the lower reaches.*

Industries

13.16 The important industries in the basin are as under:

Cotton textiles: In Surat and Burhanpur;

Silk and other fabrics: In Surat and Burhanpur;

Vegetable oils and tobacco products: In Akola;

Plastic and allied products: In Surat;

Paper, cardboard and newsprint: In Nepanagar;

Machine tools, agricultural equipment, wires and cables, machinery and machine parts, metal tubes and conduits, D.D.T. and insecticides: In Surat;

Drugs and pharmaceuticals: In Jalgaon and Surat.

Communications

13.17 The basin is served by the Central and Western Railways. The main Bombay-Baroda-Delhi line passes through its lower reaches. Some of the important lines within the basin are Surat to Bhusawal, Bhusawal to Khandwa, Jalgaon to Bombay, and Chalisgaon to Dhulia.

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*Techno-Economic Survey of Madhya Pradesh, NCAER.

The National Highways connecting Bombay, with Delhi and Ahmedabad pass through the basin. In addition, there is a network of State Highways, and district and village roads.

The Tapi is navigable in its lower reaches. The tidal influence is felt up to 48 km. upstream from the mouth of the river in the Gulf of Cambay. Surat at one time was an important river port through which international and local trade had been carried on but has lost its importance due to the development of big ports like Bombay. The size of craft plying on the Tapi vary from 25 tonnes to 100 tonnes.* Craft of 75 to 100 tonnes can ply only at high tide i.e. once or twice a fortnight. The tributaries of the Tapi are not navigable.

Dependence on Rainfall and Water Resources

13.18 The economy of the basin at present largely depends on agriculture, which, in view of the uneven incidence of rainfall, provides a low level of subsistence except where irrigation facilities have been provided or where major industries have developed. There is a keen demand for the development of the water resources of the basin.

WATER RESOURCES

13.19 The surface water potential of the Tapi river system has been assessed at different times by different authorities. The first assessment was made by the Indian Irrigation Commission (1901–03) who considered the Tapi and the Narmada river systems together. As there were no records to show the amount of surplus water passing to the sea, reliance was placed upon a co-efficient of runoff, selected with reference to the rainfall and other conditions, and to the co-efficient of actual flow, determined for other catchments. The Commission, however, cautioned that the estimates arrived at by this method must be regarded merely as rough approximations. The total annual surface flow in the Tapi and the Narmada river systems together was estimated at 70,792 m. cu. m.**

13.20 In 1949 when the assessment of the basin-wise water resources of the country was worked out on the basis of Khosla's empirical formula, the annual runoff of the Tapi river system was estimated at 9,128 m. cu. m.†

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*Navigable Waterways of India, Central Water and Power Commission (1961).

**Report of the Indian Irrigation Commission (1901-03).

†An appraisal of Water Resources by Dr. A. N. Khosla, UNESCO.

13.21 In 1960 when the irrigation potential studies of the country were made by the Central Water & Power Commission, the total annual runoff of the Tapi river system was assessed at 19,736 m. cu. m.*

13.22 River gauging in Bombay State was proposed as early as in 1902 in connection with some protective irrigation works. The site at Dholanpardi on the Tapi near the Kathore was established in 1906. Two years later, Kathore site near Bhusawal was opened in order to gauge and observe the discharges of the Tapi below its confluence with the Purna. Observations on the Girna at Jamda were started as far back as 1871. In 1906, a few new sites were opened for discharge observations on the tributaries of the Tapi-Khandhara on the Kan, Purampada on the Bori, Raipur on the Waghur and Sayagaon on the Manyad. In the next year, four more sites were opened, three on the Panjhra and Pankheda, the Dhulia and the Nyhaled and one on Mosam at Sangameshwar (near Malegaon). In 1909, one more site was opened on the Girna at Thengoda bringing the total number of sites on the tributaries to ten.

The operation of gauge and discharge sites was brought to an end on all the sites in the Tapi basin in 1926 with the exception of Thengoda and Jamda where the operations continued over the weirs for the purpose of assessing the withdrawals into the irrigation canals.

Till 1947, all hydrological activities were suspended. Towards the latter part of 1946, the Bombay Government approached the Central Water and Power Commission with a request to investigate and formulate schemes which would mitigate floods in the Narmada and the Tapi basins and enable the water resources of these basins to be utilised for irrigation, hydro-power generation etc., the necessity for hydrological observations was felt. Towards the middle of 1947, the Madhya Pradesh Government also made a similar request and steps were soon taken for a systematic collection of hydrological data. Accordingly, a number of gauge and discharge observation stations were set up under the control of the CW&PC. The details of the river gauging stations and the purpose for which each was started are shown in Table 13.11.

13.23 The Bombay State authoritities also established a number of gauge and discharge sites on the Tapi and its tributaries. The details of these sites together with the purpose with which each was established are given in Table 13.12.

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*Report of the technological possibilities of irrigation projects in India, Central Water & Power Commission—(Unpublished).

Table 13.11

River Gauging Stations in the Tapi Basin

Sl. No.	Name of the station	Year of opening	Purpose
1	2	3	4
1.	Kathore	1948	To know the yield and the maximum discharge of Tapi.
2.	Kakrapar	1949	For the Kakrapar weir project.
3.	Bhusawal	1949	To know the discharge below the confluence of the Purna with the Tapi.
4.	Ukai	1951	For the Ukai Dam Project.

Table 13.12

Gauge and Discharge Sites Set up by Bombay

Sl. No.	Name of the site	Name of the river	Year of establishing site	Purpose
1	2	3	4	5
1.	Taskheda	Tapi	1945	To know the discharge of the Tapi below the Purna river.
2.	Hotada	Tapi	1945	Warning gauge site only for floods.
3.	Purampada	Bori	1945	To know the discharge of the Bori.
4.	Saigaon	Manyad	1945	To know the discharge for lift irrigation.
5.	Jamda (Wadgaon)	Girna	1946	For the Girna weir project.
6.	Sangameshwar	Mosam	1946	For the dam across the Mosam river.
7.	Dhulia	Panjhra	1946	To know the H.F.L. of the Panjhra and for water supply to Dhulia.
8.	Pankheda	Panjhra	1947	To know the discharge of the Panjhra.
9.	Raipur	Vaghur	1947	To know the discharge of the Vaghur.
10.	Kadod	Tapi	1948	To know the high flood discharge of the Tapi.
11.	Malegaon	Mosam	1948	For irrigation scheme.
12.	Malegaon	Girna	1949	For the Malegaon irrigation project.
13.	Savkheda	Girna	1951	To know the discharge of the Girna.
14.	Jalgaon Kd.	Vaghur		To know the discharge of the Vaghur.

All the gauging stations opened by the Central Water & Power Commission continued under their aegis till 1954 when, most of them were handed over to the State Government for maintenance.

13.24 At present the gauge and discharge observations are being carried out at the sites listed below:*

Table 13.13

Existing Gauge and Discharge Sites

Sl. No.	Name of the river	Site
1	2	3
1.	Tapi	Kathore
2.	,,	Dholan Pardi
3.	,,	Kadod
4.	,,	Sarang Kheda (Takar Kheda)
5.	,,	Nanded
6.	,,	Bhusawal
7.	,,	Taskheda
8.	,,	Susti
9.	,,	Burhanpur
10.	,,	Kakrapar weir
11.	Purna	Manegaon
12.	,,	Ghodasgaon
13.	Man	Balapur
14.	Vaghur	Jalgaon Kd.
15.	,,	Raipur Tank
16.	Girna	Savkheda
17.	,,	Jamda weir
18.	,,	Malgaon
19.	,,	Thengoda weir
20.	Tittur	Patonda
21.	Manyad	Saigaon
22.	Mosam	Malegaon
23.	,,	Ambapur
24.	Aram	Satana
25.	Pan	Kalamdari
26.	Aner	Velode
27.	Bori	Purampada
28.	Panjhra	Pankheda

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*Assessment of surface water resources of Tapi basin, Central Water & Power Commission (1967)—Unpublished.

In addition to the above, gauges in the basin are being observed at the sites listed below:

Table 13.14

Gauging Sites

Sl. No.	Name of the river	Site
1	2	3
1.	Tapi	Surat
2.	,,	Ukai Dam site
3.	,,	Hatoda
4.	,,	Teska
5.	Sipna	Harisal
6.	Purna	Khiroda
7.	,,	Kholapur
8.	,,	Khurab
9.	Pedhi	Assesgaon
10.	Nala	Lakhpur
11.	Katepurna	Kurankhed
12.	Chandrabhaga	Daryapur
13.	Sapan	Ellichpur
14.	Nala	Andura
15.	Wan	Wankhed
16.	Beswa	Chandur
17.	Nalganga	Malkapur
18.	Bori	Amalaner
19.	Panjhra	Dhulia
20.	Murna	Akhola

In the Tapi basin, the gauging operations have been fairly extensive and almost all important reaches of the Tapi and its tributaries are being gauged.

Normally, two observations a day are taken. In the monsoon period when the discharges are found to vary rapidly during the day, as many as eight observations per day are made.

13.25 As in many other basins of the country, the runoff data in respect of the various gauge-discharge sites in the basin are available for only a short period, whereas the precipitation records are available for a much longer period. An attempt was made by the Central Water & Power Commission to construct a 30 years runoff series from 1930–31 to 1959–60 for the various gauge-discharge sites on the Tapi river and for the sub-basins, from the respective rainfall-runoff curves evolved from the available data. From these runoff series, the annual stream flows available for various percentages of time were worked out.

The annual stream flow thus obtained for 50%, 75% and 90% dependabilities at the five gauge-discharge sites on the main river and five major sub-basins are given below:*

Table 13.15

Annual Flow of Tapi and its Tributaries

Sl. No.	Name of the river	Site	Area in sq. km.	Stream flow in m.cu.m. available for % time or % dependability		
				90%	75%	50%
1	2	3	4	5	6	7
1.	Tapi	Burhanpur	8,935	1683.8	2727.6	3887.2
		Taskheda	29,319	2921.3	4813.4	6918.8
		Nanded	43,680	4760.4	7549.4	10648.0
		Sarangkheda	54,843	5658.8	8571.0	11806.3
		Kathore	62,704	8962.5	13235.1	17982.0
2.	Purna		18,259	321.0	1118.1	2003.9
3.	Girna		10,075	1370.9	2149.2	3014.0
4.	Vaghur		2,448	68.2	150.2	241.4
5.	Bori		1,360	205.5	321.9	451.0
6.	Aner		2,422	36.0	143.0	261.6

13.26 Like other peninsular rivers, the river Tapi swells during the monsoon months of July, August and September and the flow dwindles during the post-monsoon period. The major part of the runoff occurs in the monsoon months. From 1882 onwards, records have been maintained of flood gauges at the Hope Bridge at Surat. The data from this gauge are arbitrary. The maximum height attained by the flood was 101 in the year 1944. The flood in this year reached a record height and lasted five days. The flood discharge was roughly estimated at 27,307 cumecs. Since 1947, the Bombay Public Works Department has made arrangements to record flood discharges at Kathore Bridge, a few miles upstream of Surat. At Hope Bridge, gauge readings are being observed. Since 1953, gauge and discharge observations are being taken at Kakrapar weir.

The years in which the gauge at Hope Bridge experienced high gauges due to floods are given in Table 13.16.

Ground Water

13.27 Systematic investigations and studies of the ground water potential of some parts of the Tapi basin have been made recently.† In

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*Assessment of surface water resources of Tapi basin, Central Water and Power Commission (1967)—Unpublished.

†Ground Water Resources of India, status and surveys, Prospects and Perspectives, Geological Survey of India (August, 1970).

Table 13.16

High Floods in Tapi River

Year	Number of floods	Maximum level attained at Hope Bridge	Date of occurrence of the floods
1	2	3	4
1882	1	97.00	12th September
1883	1	100.10	3rd July
1894	1	98.30	9th September
1894	1	97.75	22nd July
1914	1	97.00	17th September
1930	1	97.50	18th September
1932	1	93.00	17th July
1933	1	98.00	18th September
1937	1	96.00	10th September
1941	2	90.50	14th July
1942	2	98.50	6th August
1944	5	101.00	17-28th August
1945	1	100.25	22-24th September
1946	2	91.75	4th August
1949	1	98.25	8th September
1954	1	96.50	29th September

the upper Tapi basin, in the Dhulia district of Maharashtra, the Deccan traps occur adjacent to the alluvial parts of the valley. These consist of fine grained massive basalts and vesicular basalts; numerous dolerite dykes cut across the flows in the basin. Ground water in the traps occurs under water-table conditions and is developed by open wells. The weathered and fractured zones of the traps form the main water-bearing horizons, which exhibit a wide range of variation in thickness as well as in hydraulic parameter. Vesicular traps occurring at shallow depths also form an important water-bearing zone. Open wells of large dimensions piercing the maximum thickness of the weathered and fractured zones as well as vesicular lavas are the most suitable for ground water development in this area.

The narrow area of the shallow valley fill portion is underlain by the alluvial material of the river. The alluvium comprises clays, silt, sand, gravel and boulders. The maximum thickness is about 46 m. in Dhulia district while it is about 306 m. in certain narrow and isolated sectors in the Jalgaon district. The alluvial fan deposits near the foot-hills of the Satpuras consist of loose boulders, pebbles and gravel beds, which form re-charge zone of ground water for the major part of the valley north of the Tapi. Ground water in the alluvial areas occurs both under water-table and confined conditions. The chief aquifer zones consist of sand, gravel and boulders. Ground water in the area is mainly developed by dug and dug-cum-bore wells. There is scope for ground water development in the area if the wells are properly planned and designed. The chemical quality of the ground water is uniformly good for irrigation.

Exploratory drilling carried out in the Rajora, Raver and Korpavli areas in the basin has indicated that there is a possibility of ground water development by heavy duty tubewells. Also small-scale development in areas around Taloda, Savalda, Adavad and Yaval is possible. In the rest of the Tapi valley, large-scale development is not possible. The sand and aquifer deposits along numerous streams and rivers south of the Tapi can be tapped by suitable dug wells and infiltration galleries.

In the Purna sub-basin, investigations have indicated that the alluvial fill of the valley is of quarternary age and is underlain by the Deccan traps and older rocks. The alluvium consists of sand, silt, gravel and boulders. Due to the high proportion of clay, no granular zone can be delineated. Along the Gawilgarh hills there is a belt of boulders and sediments, which forms a promising aquifer. The maximum thickness of the alluvium is 130 m. The area adjoining the Gawilgarh hills forms the recharge area. Ground water in the area is mainly developed by open and dug-cum-bore wells. It occurs both under water-table and confined conditions. Ground water development on a moderate scale by means of open wells and dug-cum-bore wells is possible in this area.

The investigations carried out so far point to the urgency and importance of carrying out further exploratory work in the Tapi basin for a quantitative and qualitative assessment of the ground water resources on a scientific basis. It is only when such investigations have been carried out that a correct assessment of the ground water resources of the basin can be made, which will help in framing a rational plan of development for various needs.

EXISTING DEVELOPMENT

13.28 Irrigation has been practised in the basin from early times. The earliest irrigation work in the basin was the Jamda weir across the Girna river, with a canal system.

The Jamda weir is located across the river Girna, just above the railway bridge, south-west of Jamda village. It is 469 m. long with a height of 3.7 m. above the river bed. The project was completed in 1902 by the then Bombay State, at a cost of Rs. 1.09 million. Two canals one on either bank take off from the weir to irrigate a total area of 3,560 hectares annually.

13.29 Prior to Independence, the policy of the Government had been to construct irrigation works to provide protection against famine. Since the Tapi tract was not subject to any serious famines, the utilisation of its water resources had not been given serious consideration. Moreover, the fact that the soil in the basin is generally moisture retentive and could produce a fairly good harvest even in years of scanty rainfall, inhibited the development of any large-scale irrigation in the basin. The Indian Irrigation Commission had made the following remarks in respect of irrigation in the Tapi basin:

> "Canals from the Nerbudda and Tapi appear to us to be less urgently required as a measure of protection from famine, and great caution must be exercised in introducing canal irrigation in the black cotton soil tracts of Gujarat. A Nerbudda Canal in black soil could not possibly pay, or be justified except for the protection of the country in seasons of extreme drought. The country to be irrigated by the Tapi is not sufficiently exposed to severe famine to justify the execution of the canal for purely protective purposes. It should be undertaken only if likely to prove remunerative, though not necessarily highly remunerative, for purposes of rice irrigation on lands not required for the growth of cotton. But, as already indicated, the proposals which have been laid before us do not cover the ground; and for the ascertainment of the possibilities of irrigation in Gujarat a comprehensive examination of the country is absolutely essential. Subject, however, to the precautions which we have recommended, we think it possible that a canal from the Tapi can be made which will be beneficial to the country without imposing any permanent liability on the State, and we recommend that the matter be taken up as soon as may be convenient."

No large irrigation works had been undertaken in the pre-Independence period. The only earlier projects worth mentioning are the Chankapur Dam and the Thengoda Weir with their canal systems in the Girna subbasin. In addition to these there were some other small schemes like the Paroul Tank, the Sukhi nalla (Jhadi Tank) project, the Mahada Irrigation Tank and the Nepa Weir which were also constructed in the basin. Of these, the first three were constructed for irrigation. The Nepa Weir was constructed by the Nepa Paper Mills for their use. These earlier projects are briefly described in the following paragraphs.

Chankapur Dam and Thengoda Pick-up Weir

The Chankapur dam is situated on the river Girna below its confluence with the Tombat river close to the small Bhil hamlet of Chankapur, 16 km. west of Kalvan. The dam is 181 m. long and has a maximum height of 43 m. above the foundations. The Thengoda pick-up weir is situated lower down across the Girna, 37 km. east of the

Chankapur dam. It is 335 m. long with a maximum height of 3 m. above the foundations. The canal system taking off from the Thengoda weir irrigates annually an area of 8,093 hectares.

Bandharas

A net-work of minor irrigation works, which are really small pick-up weirs, commonly known as bandharas, were also constructed in the pre-Independence period, in the basin. These are scattered throughout the Khandesh districts of Maharashtra. Other areas in which they are found are the Nasik district of Maharashtra and the Khargone district of Madhya Pradesh. Almost every village in this tract has its own bandhara and accompanying water courses for conveying water. Bandharas have been constructed by taking advantages of rock outcrops in the bed and banks. They are made by filling in the gaps with common basalt stones laid in surkhi mortar of lime mixed with pieces of brick. No provision was normally made to drain off silt except through some small openings in the middle of the base of Bandharas. Because of this deficiency a number of bandharas had to be abandonded as they got silted up. The water courses leading from the bandharas are small with irregular bed falls. The main aim of the bandharas is to supply water throughout the year to the more valuable crops. A rotation of crops of which sugarcane and other garden crops form the principal items is practised.

13.30 Some details of the pre-Plan schemes are given below:

Table 13.17

Pre-Plan Irrigation Works

Sl. No.	Name of the scheme	River or tributary	Ultimate irrigation in thousand hectares
1	2	3	4
1.	Chankapur Dam and Thengoda pick-up weir	Girna	8.09
2.	Jamda weir and canals	,,	3.56
3.	Parsul tank	Parsul	0.76
4.	Sukhi	Sukhi	1.21
5.	Meshwa tank	Bori	0.47
6.	Tapi weir at Nepanagar*	Tapi	Nil
7.	Bandharas	Minor tributaries	12.04

*This is not an irrigation scheme. The weir is constructed for the utilisation of water in the paper mill at Nepanagar.

13.31 In the post-Independence period, which was also a period of food shortages, the necessity for irrigation were realised. In the Tapi basin, the major Kakrapur project was taken up in the Gujarat State during the First Five Year Plan. Subsequently, during the Second Plan, two more major projects, namely Ukai in Gujarat and Girna in Maharashtra were started. These projects are described briefly in the following paragraphs.

Kakrapar weir and canals project

The project consists of a pick-up weir across the river Tapi as it debouches from the hilly and forested tracts into the plains of Gujarat near Kakrapar, about 80 km. upstream of Surat in Gujarat State. The weir has a total length of 621 m. and has a maximum height of 14 m. The weir has canal systems on both banks, the total length of the main canals and branches being about 435 km.

The project costing Rs. 180.5 million commands a gross area of 3.24 lakh hectares and annually irrigates 227,530 hectares. It was taken up for construction in the year 1949 and is likely to be completed during the Fourth Plan. The weir has been completed and the construction of the canal system is nearing completion.

Ukai Project

The project envisages a composite dam across the river Tapi near village Ukai in the Songadh Taluka of Surat district in Gujarat State, about 116 km. upstream of Surat. The dam is 4,927 m. long and has a maximum height of 69 m. above the foundation. The reservoir will have a gross storage of 8,511 m. cu. m., of which 7,092 m. cu. m. will be live storage and the remaining 1,419 m. cu. m. dead storage. Two canals, one on the left bank taking off directly from the dam and the other on the right bank taking off from the Kakrapar weir, will be constructed for providing irrigation to an area of 152,400 hectares in the Surat and Broach districts of Gujarat. The project will also firm-up irrigation under the Kakrapar weir. In addition, the waters stored in the reservoir would be utilised for the generation of about 193 MW of firm power at 35% load factor. The project would also afford flood protection to the area lower down.

The Ukai Dam Project is estimated to cost Rs. 1,044 million (Irrigation & Power). The project was taken up for execution in 1960. The headworks are likely to be completed by the end of the Fourth Plan and canals during the Fifth Plan.

Girna Project

The project envisages the construction of:

(i) a dam across the river Girna near village Panzan, 26.6 km. from Nandgaon railway station, in district Nasik of Maharashtra State
(ii) a weir across the river Girna near village Jamda, about 10 km. north of Chalisgaon in Maharashtra State
(iii) a weir near village Dahigaon, 19 km. from Erandole in Maharashtra State
(iv) a canal system to irrigate an area of 57,208 hectares annually.

The dam will be 963 m. long, with a maximum height of 55 m. The gross storage of the reservoir will be 611.8 m. cu. m. of which 526.7 m. cu. m. will be live and the remaining 85.1 m. cu. m. dead storage. The Jamda and the Dahigaon weirs will be 396 m. and 423 m. long respectively. The Jamda main canal will be 109 km. long and the Dahigaon main canal 89 km.

The project, estimated to cost Rs. 146.00 million, was taken up for construction in 1956 and is likely to be completed during the Fourth Plan.

13.32 In addition to the above major projects, a number of medium schemes were also taken up in the Tapi basin during the various Five Year Plans. Most of these lie in Maharashtra State. Of all the medium schemes taken up for execution, only three viz. Mosam Bandhara Project and Nalganga Project—Stage I in Maharashtra and the Bandhara across the Ver river in Gujarat have so far been completed. Some details of the various medium schemes taken up for execution in the Tapi basin during the various Plan periods are given in Table 13.18.

The particulars of the various projects completed and those under construction in the various States in the Tapi basin are given in Appendices 13.1 and 13.2 respectively.

13.33 Besides the major and medium projects, a number of minor schemes comprising wells and tanks, irrigate a considerable area in the basin. The details of the area irrigated by various sources like canals, tanks, wells etc. during the year 1967–68 in the basin are shown in Table 13.19.

13.34 In the absence of data regarding annual diversions and utilisations by the major and medium projects under operation and construction as in 1968-69 in the basin, on the basis of assumed duties, the utilisation has been approximately estimated to be of the order of 4,806 m. cu. m.

Table 13.18

Details of Medium Schemes Undertaken During the Plan Periods in the Tapi Basin

Sl. No.	Name of the project	River/ Tributary	Estimated cost (Rs. million)	Ultimate irrigation (Thousand hectares)	Completed under construction
1	2	3	4	5	6
Maharashtra					
1.	Mosam Bandhara	Mosam	3.61	3.15	Completed
2.	Nalganga Project—Stage I	Nalganga	27.32	8.74	-do-
3.	Katepurna Project—Stage I	Katepurna	41.27	8.35	Under construction
4.	Malangaon Tank	Kan	7.42	2.26	-do-
5.	Karwand Dam	Arunavathi	17.40	4.53	-do-
6.	Morna River Project	Morna	17.30	5.26	-do-
7.	Gyanganga River Project	Gyanganga	19.00	4.37	-do-
8.	Chankapur Dam	Girna	22.00	12.04	-do-
9.	Panzara	Panzara	18.31	7.77	-do-
10.	Nirguna	Nirguna	18.98	8.75	-do-
11.	Manyad Project	Manyad	17.50	6.86	-do-
12.	Kanholi	Kanholi	4.14	1.05	-do-
Gujarat					
13.	Bandhara across river Ver	Ver	0.90	1.38	Completed

Table 13.19

Source-wise Irrigation

Sl. No.	Source of Irrigation	Area irrigated ('000 hectares)			Total
		Madhya Pradesh	Maharashtra	Gujarat	
1	2	3	4	5	6
1.	Canals	1.40	20.10	10.30	31.80
2.	Tanks	0.10	Neg.	0.80	0.90
3.	Wells	15.10	122.40	5.50	143.00
4.	Other sources	0.30	1.50	0.30	2.10
		15.90	144.00	16.90	177.80

As regards the statistics of a large number of minor schemes, no information is available. Based on the area irrigated from these sources and on rough duties, an approximate estimate of the quantity of water diverted for irrigation by these works has been made. The quantity works out to 1,577 m. cu. m.

Reservoir Losses

13.35 On the basis of assumptions detailed in para 1.33 the reservoir losses from the various schemes in the basin will be as under:

(i) Major and Medium Schemes	532 m. cu. m.
(ii) Minor Schemes (tanks)	13 m. cu. m.
Total	545 m. cu. m.

13.36 Thus, the major, medium and minor projects under operation and construction (in 1968-69) in the basin would use about 6,928 m. cu. m. on completion and full development, of which 5,383 m. cu. m. is from surface waters and 1,545 m. cu. m. from ground waters.

13.37 There are a number of industries located in the basin, especially around Surat, Akola, Burhanpur, Jalgaon and Nepa Nagar. The data on present industrial water needs are not readily available. In future, such needs are expected to grow. The problem of water pollution in the basin due to the discharge of industrial wastes has not been reported thus far. However, such a problem may arise in the future, and will have to be dealt with.

FUTURE DEVELOPMENT

13.38 One major and three medium projects are proposed to be taken up for construction in the Fourth Plan period. Of these, one major project and two medium projects are in Maharashtra and one medium project is in Madhya Pradesh. Appendix 13.3 shows the salient features of these projects. The Upper Tapi Project, which is a major project, is described briefly in the following paragraph.

Upper Tapi Project

The project envisages the construction of a gated weir across the Tapi river near village Hatnur in the Jalgaon district of Maharashtra State with a right bank canal, 96.6 km long. The project, on completion, will irrigate an area of 55,246 hectares. The estimated cost is Rs. 120.9 million. The project is under construction and is expected to be completed by the beginning of the Fifth Plan.

On completion and full development, the Fourth Plan projects will utilise about 746 m. cu. m. of the Tapi waters including reservoir losses.

By the end of Fourth Plan, the area under minor schemes is expected to increase by about 123,940 hectares requiring nearly 1,141 m. cu. m. of waters including reservoir losses.

Thus, the additional utilisation by the Fourth Plan major, medium and minor projects would be of the order of 1,887 m. cu. m. benefiting an area of 192,010 hectares.

On full development of Fourth Plan projects, a total quantity of about 8,815 m. cu. m. (of which 6,161 m. cu. m. is from surface waters and 2,654 m. cu. m. from ground waters) would have been used for irrigating a total area of 890,150 hectares, including area irrigated by the river outside the basin.

After completion and full development of the Fourth Plan projects, there would still be a large quantity of water available in the river for utilisation by future projects. Several new schemes have been proposed in the basin by the States concerned in the basin. The names of the new major and medium projects proposed by the different States are given in Appendix 13.4. Details of these schemes are not available.

FLOODS, WATERLOGGING & DRAINAGE

13.39 The Tapi basin is influenced by the south-west monsoon. The flows in the river are considerable during the monsoon period, dwindle rapidly in the post-monsoon season and become negligible in the hot weather. High floods are experienced in the monsoon months. The highest flood discharge as observed at Hope Bridge in Surat in August 1944 was of the order of 27,307 cumecs. As the river flows in a defined channel with fairly high banks for a considerable part of its length, damage due to floods has not occurred on a large-scale. It is only in the lower reaches of the river that severe damage has occurred due to floods which have affected Surat City and surrounding areas. So far, no major flood control works have been constructed in the basin. The Ukai multipurpose project, which is under construction, will afford partial flood control in the Gujarat plains. A scheme for constructing protective bunds on the banks of the Tapi near Surat is also under consideration. This will protect the city and the adjoining areas from flooding to some extent.

13.40 Waterlogging occurs in the low lying coastal areas in Surat district due to defective drainage. Waterlogging in the areas under the irrigated commands in the basin has not been severe so far, as there is very little perennial irrigation. The only reported cases relate to areas under the Girna left bank canal in Maharashtra and the Kakrapar canals in Gujarat. The areas affected under the Girna left bank canal by waterlogging and salinity are 76 hectares and 805 hectares respectively. Under the Kakrapar system, due either to the blocking of the internal drainage or the fact that it is low lying area, waterlogging had taken place. This has been remedied by constructing artificial surface drains and clearing existing drains up to their outfall. The Gujarat State has some proposals for the construction of surface drains to remove waterlogging in the irrigated areas under the Kakrapar system.

SOIL CONSERVATION

13.41 Soil and water conservation measures were started in the then Bombay State in 1942, with the main object of preventing soil erosion and conserving moisture for successful agricultural production in the dry areas. These measures comprise contour and graded bunding, bench terracing for paddy etc. The work done in the Tapi basin till the end of August, 1969 in Maharashtra State is shown below:

Table 13.20

Progress of Soil Conservation Works

Sl. No.	Basin	Bundable area in hectares	Area bunded so far in hectares	Area terraced so far in hectares	Remarks
1	2	3	4	5	6
1.	Purna	1,202,469	455,606	—	
2.	Tapi	1,243,684	645,323	—	
	Total	2,446,153	1,100,929	—	

13.42 In order to carry out a detailed study in respect of the soil and moisture conservation work in river valley projects, the Government of Maharashtra had appointed a study group in 1962, consisting of members from the Agriculture, Forest and Irrigation & Power Departments. The study group was (i) to consider the vulnerability of particular catchment areas under river valley projects to the hazards of soil erosion and (ii) to draw up a list of vulnerable catchments and recommend a scheme for co-ordinating different soil conservation works in those catchments which were considered to be most vulnerable. After a detailed study of the catchments of river valley projects taken up during the Second Five Year

Plan, the study group graded the river valley projects in order of vulnerability to soil erosion. The Girna Project was included in the list of vulnerable projects.

The soil and water conservation operations already in progress will cover agricultural land in catchment areas. Contour and graded bunding operations, will minimise the problem of silting in major and medium reservoirs. After taking into consideration the silt load, the rainfall and its characteristics, soil vegetal cover and topography etc., the catchments of major and medium projects have been graded for consideration under the afforestation programme in the Fourth Five Year Plan of the State. The projects of the Tapi basin included in this programme are given below:

Table 13.21

Fourth Plan Afforestation Programme in Tapi Basin

Sl. No.	Name of the catchment	Area in sq. km.	Remarks
1	2	3	4
1.	Katepurna	578	
2.	Nalganga	316	
3.	Girna	8,158	

13.43 No data is available regarding the silting of existing tanks and reservoirs in the basin. For the conservation of river supplies and especially of the storage capacity created in the reservoirs, it is important that soil conservation measures should be taken up both in the cultivated areas and in the culturable but uncultivated areas of the Tapi basin and in the areas under forests.

13.44 The soil conservation measures to be taken may be classified under the following heads:

(i) Afforestation—in new areas as well as in the existing forests which have been either denuded or where replacement is needed.

(ii) Terracing and contour bunding on agricultural lands which require treatment by soil conservation practices.

(iii) Pasture development and protection of marginal and sub-marginal lands.

(iv) Stream control measures including fringe afforestation and stream bank control.

(v) Silt clearance works on principal streams and rivulets, check dams etc.

GENERAL

13.45 The Tapi and its tributaries are an inter-State river system flowing through the States of Madhya Pradesh, Maharashtra and Gujarat. In March, 1964 an agreement was reached between the Madhya Pradesh and Maharashtra States with regard to the construction of the Upper Tapi Multipurpose project. Subsequently, in December, 1968 an inter-State meeting was held between the Chief Ministers of Madhya Pradesh and Maharashtra to discuss certain irrigation and hydel projects concerning the two States. An agreement was signed for the construction of twelve projects, four of which, namely (i) Upper Tapi Project—Stage I, (ii) Upper Tapi Project—Stage II, (iii) Sukhi and (iv) Aner, lie in the Tapi basin.

13.46 A network of evaporation measuring stations particularly at the sites of existing and proposed reservoirs should be established in the basin.

13.47 Gauge and discharge observations at the various sites should be continued on a permanent basis, to obtain data essential not only for the preparation of individual projects but also for the regulation of available river water.

13.48 Systematic and scientific exploratory work is needed for a quantitative and qualitative assessment of the ground water resources in the basin, so that these resources can be exploited rationally, either independently or in conjunction with the surface waters.

13.49 There is need for inter-State co-operation and agreement in respect of soil conservation measures and to conserve the storage capacities of existing and proposed reservoirs in the basin.

13.50 It is necessary that systematic data should be collected of the sediment carried by the rivers which would be of considerable use in working out dead storage and the life of reservoirs. It will also reflect the effect of soil conservation works carried out in the basin.

THE KIM BASIN

13.51 The Kim basin is located in between the Tapi and the Narmada basins in Gujarat State. It extends over an area of 1,779 sq. km. and lies between east longitudes 72°33′ and 73°28′ and north latitudes 21°7′ and 21°35′.

13.52 The Kim river rises south-west of village Koyalimandvi in the Broach district of Gujarat at an elevation of about 50 m. at north latitude 21°32′ and east longitude 73°20′ and flows in a generally westerly direction for a total length of 97 km., to outfall into the Gulf of Cambay.

13.53 The basin experiences four seasons in the year namely (i) winter, (ii) summer, (iii) monsoon and (iv) post-monsoon.

13.54 There are 7 reporting rain-gauge stations inside the basin. The distribution of the stations is fairly even and the number is also sufficient. The annual rainfall in the basin varies from 889 to 1,270 mm. 95 per cent of the rainfall occurs during the monsoon months from June to September.

13.55 The temperature variations in the basin during the different seasons are as under:

Season	*Mean Temperature*
Winter	20.0°C to 22.5°C
Summer	30.0°C to 32.5°C
Monsoon	27.5°C to 30.0°C
Post-monsoon	27.5°C

13.56 Evaporation data for the basin is not available.

13.57 Systematic soil survey of the basin has not been done. The general data on soils of the country indicates that the basin consists of mainly deep black soils and coastal alluvium. The basin covers partly the districts of Broach and Surat in Gujarat State. In the Broach district mainly deep black soils occur whereas in the Surat district both deep black soils and coastal alluvium are found.*

13.58 The land use details in the basin as in 1967–68, the latest year for which the statistics are available are given in Table 13.22.

Area under irrigated crops is about 8.8 per cent of the cropped area in the basin.

Of the gross irrigated area of about 10,500 hectares, nearly 19.1% is under rice, 24.8% under cotton, 9.5% under jowar, 5.7% under sugar-

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*Indian Crop Calendar, Ministry of Food & Agriculture, C. D. & Cooperation, 1967.

Table 13.22

Land Use Details in the Kim Basin

Sl. No.	Item	Area in '000 hectares
1	2	3
1.	Gross area	178
2.	Reporting area	178
3.	Area under forests	40
4.	Area not available for cultivation	19
5.	Culturable area	119
6.	Uncultivated culturable area	13
7.	Net area sown	106
8.	Area sown more than once	5
9.	Total cropped area	111
10.	Net irrigated area	10.1
11.	Gross irrigated area	10.5
12.	Percentage of net area sown to culturable area	89.1%
13.	Percentage of net irrigated area to culturable area	8.5%
14.	Percentage of net irrigated area to net area sown	9.5%

cane, 8.6% under wheat and the rest under other crops like bajra, condiments, spices, groundnut, tobacco and fodder crops. Food and non-food crops cover 71.4% and 28.6% of the irrigated cropped area respectively.

13.59 There are two crop seasons namely (i) kharif and (ii) rabi. Kharif crops are sown in the period June-August and harvested from September-December. The rabi crops are sown in September-November and harvested from January-March.

13.60 On the basis of 1971 census* and percentages of the area of each district within the basin to the district as a whole, the total population in the basin is about 0.39 million. There is no city having population of more than one lakh. Average density of the population in the basin is 219 persons per sq. km. The densities of population in the Broach and Surat districts are 122 persons per sq. km. and 255 persons per sq. km. respectively.

13.61 Forests cover 22.5 per cent of the basin area. The area annually cropped in the basin is about 0.11 million hectares. Agriculture is generally rainfed with relatively low yields except for about 10,500 hectares of irrigated area which mainly grows rice and cotton.

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*Census Paper I of 1971 (Supplementary), Registrar-General (India).

Neither hydro nor thermal power stations are located in the basin at present.

Manganese is the only important mineral that is found in the upper reaches of the basin.

There are no major industries located in the basin.

The basin is served by the Western Railway. The National Highway connecting Bombay and Ahmedabad passes through the basin, in addition to the State highways and several district roads. The river is not navigable. The basin has fairly well developed communications.

13.62 There is no gauge and discharge site in the basin. It is essential that a few gauge and discharge sites are established in the basin and observations conducted in a systematic manner. The total annual flow of the basin has not been assessed so far.

13.63 A part of the basin explored by the Geological Survey of India indicates that the area is underlain by Tertiary Sediments.* Two boreholes drilled and electrically logged show that the Tertiaries in the area are locally productive. Systematic exploratory work has to be done to assess quantitatively and qualitatively the ground water resources.

13.64 There are no major and medium projects constructed in the basin either in the pre-plan or the plan periods. All the projects, existing and under construction in the basin are minor schemes. However, a large part of the basin falls under the command of the Ukai Right Bank Canal. Details of the area irrigated by various sources like canals, tanks, wells etc. during the year 1967–68 are as under:

Table 13.23

Source-wise Irrigation—Kim Basin

Sl. No.	Source of irrigation	Area irrigated ('000 hectares)
1.	Canals	4.4
2.	Tanks	0.9
3.	Wells	4.5
4.	Other sources	0.3
	Total	10.1

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*Ground Water Resources of India, Status and Survey, Prospects and Perspectives, Geological Survey of India (August, 1970).

The area under minor schemes increased by 690 hectares in 1968–69.

13.65 As per the data furnished by the Gujarat State, there were no minor schemes existing in the basin prior to 1950. During the period 1950–69, the following minor schemes have been constructed in the basin:

Table 13.24

Existing Minor Schemes in Kim Basin

Sl. No.	Name of the scheme	Location/District
1.	Buran	Surat
2.	Mokhadi	Broach

There is only one minor scheme namely the Dolatpur Scheme which is under construction in the basin. It is located in the Broach district.

13.66 Information in respect of the utilisation by the minor schemes is not available. On the basis of the total area irrigated by the minor schemes in 1968–69, the Commission has estimated the approximate utilisation as 109 m. cu. m. (including reservoir losses), of which 65 m. cu. m. is from surface waters and 44 m. cu. m. from ground waters.

Two medium projects, namely (i) the Baldeva Scheme and (ii) the Pigat Scheme, are proposed to be taken up by the Gujarat State in future in the basin. Some details of these schemes are as under:

Table 13.25

Proposed Medium Schemes—Kim Basin

Sl. No.	Name of the Project	Zone/District	Estimated cost Rs. million	Source of supply	Type (Flow/Storage/Lift)	Ultimate irrigation (hectares)
1	2	3	4	5	6	7
1.	Baldeva	Broach	4.558	On a tributary of the Kim	Storage	1,580
2.	Pigart	„	1.663	Tokri	„	405

13.67 There is no serious flood problem in the basin. However, when both the Narmada and the Tapi are simultaneously in high floods, the two flood plains join together causing flood problem in the intermediate Kim basin. No flood control measures have been undertaken.

13.68 No soil conservation measures appear to have been undertaken in the basin. As the basin has hardly 15.73 per cent area under forests, afforestation is called for to reduce the erosion hazards. Other soil conservation measures on agricultural lands also need to be taken up to conserve the storage capacities of the reservoirs in the basin.

GENERAL

13.69 Evaporation measuring stations need to be established.

Gauge and discharge observation sites need to be established and observations conducted in a systematic manner.

Systematic and scientific exploratory work has to be undertaken for the qualitative and quantitative assessment of the ground water resources.

Data with regard to the sediment load needs to be collected.

SALIENT FEATURES OF THE NARMADA BASIN

(i) Source: Near Amarkantak in Shahdol district of Madhya Pradesh (Latitude 22°40′N, Longitude 81°45′E)

(ii) Length:

Madhya Pradesh;	1079 km.	670 miles
Common boundary between Madhya Pradesh and Maharashtra	35 km.	22 miles
Common boundary between Maharashtra and Gujarat	39 km.	24 miles
Gujarat	159 km.	99 miles
Total	1312 km.	815 miles

(iii) Drainage

Area:	Sq. km.	Sq. miles
Madhya Pradesh	85,859	33,150
Maharashtra	1,538	594
Gujarat	11,399	4,401
Total	98,796	38,145

(iv) Population (1971 Census)	10.60 millions	
(v) Density of population	107 per sq.km.	277 per sq.mile.
(vi) Maximum discharge	Cumecs	Cusecs
At Garudeshwar on 17th Sept' 1950	39,644	1,400,000
(vii) Minimum discharge		
At Garudeshwar on 10th June, 1952	10.3	364
(viii) Annual runoff:	M.cu.m.	MAF
(*a*) at 90% dependability at Navagam	27,864	22.59
(*b*) at 75% „ „ „	35,672	28.92
(*c*) at 50% „ „ „	44,331	35.94
(ix) Maximum annual runoff recorded todate at Garudeshwar in 1944:	75,045	60.84
	(Extrapolated from observed data)	
(x) Minimum annual runoff recorded todate at Garudeshwar in 1918:	17,355	14.07
	(Extrapolated from observed data)	

			Thousand hectares	Thousand acres
(xi)	Culturable area (1967-68)		5,901	14,582
(xii)	Net area sown (1967-68)		4,499	11,117
(xiii)	Gross area sown (1967-68)		4,762	11,767
(xiv)	Net area irrigated (1967-68)		202	500
(xv)	Gross area irrigated (1967-68)		214	528
(xvi)	Area irrigated after completion and full development of Fourth Plan Projects (excluding Navagam Project)		1,021	2,524
(xvii)	Water utilisation, including reservoir losses:		M.cu.m.	MAF
	(*a*) On completion & full development of major, medium & minor projects under operation and construction in 1968-69	Surface waters	2,786	2.26
		Ground waters	1,372	1.11
	Total		4,158	3.37
	(*b*) On completion and full development of Fourth Plan projects (excluding Navagam project)	Surface waters	8,046	6.52
		Ground waters	2,514	2.04
	Total		10,560	8.56

CHAPTER XIV

THE NARMADA BASIN

The Narmada Basin extends over an area of 98,796 sq. km. and lies between east longitudes 72°32′ to 81°45′ and north latitudes 21°20′ to 23°45′. Lying in the northern extremity of the Deccan plateau, the basin covers large areas in the States of Madhya Pradesh and Gujarat and a comparatively smaller area in Maharashtra. The State-wise distribution of the drainage area is as under:

Table 14.1

Drainage Area—State-wise

Name of State	Drainage area
1	2
Madhya Pradesh	85,859 sq. km.
Maharashtra	1,538 sq. km.
Gujarat	11,399 sq. km.
Total	98,796 sq. km.

14.2 The Narmada Basin is bounded on the north by the Vindhyas, on the east by the Maikala range, on the south by the Satpuras and on the west by the Arabian Sea. The basin has an elongated shape with a maximum length of 953 km. from east to west and a maximum width of 234 km. from north to south. The basin has five well-defined physiographic regions. They are (i) the upper hilly areas covering the districts of Shahdol, Mandla, Durg, Balaghat and Seoni, (ii) the upper plains covering the districts of Jabalpur, Narsimhapur, Sagar, Damoh, Chhindwara, Hoshangabad, Betul, Raisen and Sehore, (iii) the middle plains covering the districts of East Nimar, part of West Nimar, Dewas, Indore and Dhar, (iv) the lower hilly areas covering part of the West Nimar, Jhabua, Dhulia and parts of Baroda and (v) the lower plains covering mainly the district of Broach and parts of Baroda. The hilly regions are well forested. The upper, middle and lower plains are broad and fertile areas well suited for cultivation.

THE RIVER SYSTEM

14.3 The Narmada, the largest west-flowing river of the peninsula rises near Amarkantak, in the Shahdol district of Madhya Pradesh, at an elevation of about 900 m. at north latitude 22°40′ and east longitude 81°45′ in the Maikala range. The river has a number of falls in its head reaches. At 8 km. from its source, the river drops 21 to 24 m. at Kapildhara falls. 0.4 km. further downstream, it drops by about 4.6 m. at the Dudhdhara falls. Its first major tributary, the Burhner joins the Narmada from the left, at the 248th km. of its run. Flowing in a generally south-westerly direction in a narrow and deep valley, the river takes pin-head turns at places. At the 286th km. from the source, it turns north-wards and hardly a km. further downstream it receives the Banjar, another major tributary from the left, and flows past Mandla town in a number of channels called Sahasradhara. Close to Jabalpur, 404 km. from the source, the river drops nearly 15 m. at the Dhuandhara falls, after which it flows through a narrow channel carved through the famous marble rocks.

Emerging from the marble rocks, the Narmada enters the upper fertile plains and at the 464th km. of its run, receives the Hiran, a major right bank tributary. Continuing to flow in a westerly direction through the upper plains, the river receives several tributaries like the Sher, Shakkar, Dudhi, Tawa, Gangal from the left and the Tendoni, Barna, Kolar from the right.

Flowing further west, it enters the middle plains near Panghat in East Nimar district. At Mandhar, 806 km. from the source and at Dhardi, 47 km. further downstream, the river drops over falls of 12 m. at each place. At the 966th km. from the source, nearly 6.4 km. downstream of Maheshwar, the Narmada again drops by about 6.7 m. at the Sahasradhara falls. During its journey through the middle plains, it receives the Chhota Tawa, the Kundi from the left and the Man from the right.

Flowing further west, the river enters the lower hilly regions and flows through a gorge, receiving the Goi from the left and the Uri, the Hatni from the right. The 113 km. long gorge is formed by the converging of the Vindhyas from the north and the Satpuras from the south towards the river.

Emerging from the gorge, the river enters the lower plains and meanders in broad curves till it reaches Broach. The Karjan from the left and the Orsang from the right are the important tributaries joining the river in this reach. Beyond Broach, the valley widens into an estuary. Finally, the river enters the Gulf of Cambay.

The total length of the river from the head to its outfall into the sea is 1,312 km. The first 1,079 km. are in Madhya Pradesh. In the next length of 35 km., the river forms the boundary between the States of Madhya Pradesh and Maharashtra. Again, in the next length of 39 km., it forms the boundary between Maharashtra and Gujarat. The last length of 159 km. lies in Gujarat.

14.4 The important tributaries of the Narmada are described briefly in the following paragraphs.

The Burhner rises in the Maikala range, south-east of Gwara village in Mandla district of Madhya Pradesh at an elevation of about 900 m., at north latitude 22°32′ and east longitude 81°22′ and flows in a generally westerly direction for a total length of 177 km. to join the Narmada near Manot. The Burhner drains a total area of 4,118 sq. km.

The Banjar rises in the Satpura range in the Durg district of Madhya Pradesh near Rampur village at an elevation of 600 m. at north latitude 21°42′ and east longitude 80°50′ and flows in a generally north-westerly direction for a total length of 184 km. to join the Narmada from the left near Mandla at the 287th km. of its run. The Banjar drains a total area of 3,626 sq. km.

The Sher rises in the Satpura range near Patan in the Seoni district of Madhya Pradesh at an elevation of 600 m. at north latitude 22°31′ and east longitude 79°25′ and flows in a generally north-westerly direction for a total length of 129 km. to its confluence with the Narmada from the left near Brahmand. The Sher drains a total area of 2,901 sq. km.

The Shakkar also rises in the Satpura range in the Chhindwara district of Madhya Pradesh, east of Chhindi village, at an elevation of 600 m. at north latitude 22°23′ and east longitude 78°52′ and flows in a generally north-westerly direction for a total length of 161 km. to join the Narmada from the left, north-west of Paloha. The Shakkar drains a total area of 2,292 sq. km.

The Dudhi rises in the Mahadeo hills of the Satpura range in the Chhindwara district of Madhya Pradesh, west of Chhindi village at an elevation of 900 m. at north latitude 22°23′ and east longitude 78°45′ and flows first in a north-westerly direction up to Sainkheda and then in a westerly direction for a total length of 129 km. to join the Narmada from the left, north-west of Nibhora. The Dudhi drains a total area of 1,541 sq. km.

The Tawa, the biggest left bank tributary, rises in the Mahadeo hills of the Satpura range in the Chhindwara district of Madhya Pradesh near Cherkathari village at an elevation of 900 m. at north latitude 22°13′ and east longitude 78°23′ and flows in a generally north-westerly direction for a total length of 172 km. to join the Narmada from the left, north-east of Hoshangabad. The Denwa is its important tributary. The Tawa drains a total area of 6,333 sq. km.

The Ganjal rises in the Satpura range in the Betul district of Madhya Pradesh, north of Bhimpur village at an elevation of 800 m. at north latitude 22°0′ and east longitude 77°30′ and flows for a total length of 89 km. in a north-westerly direction to join the Narmada from the left near Chhipaner village. The Ganjal drains a total area of 1,930 sq. km.

The Chhota Tawa rises in the Satpura range in the West Nimar district of Madhya Pradesh near Kakora village at an elevation of 600 m. at north latitude 21°30′ and east longitude 75°50′ and flows for a total length of 169 km. in a northerly direction to join the Narmada from the left, north of Purni village. The Chhota Tawa is next in size to the Tawa among the left bank tributaries and drains a total area of 5,051 sq. km.

The Kundi rises in the Satpura range in West Nimar district of Madhya Pradesh, near Tinshemali village at an elevation of 600 m. at north latitude 21°25′ and east longitude 75°45′ and flows for a total distance of 121 km. in a northerly direction to join the Narmada from the left near Mandleshwar. The Kundi drains a total area of 3,820 sq. km.

The Goi rises in the Satpura range in West Nimar district of Madhya Pradesh near village Dhavdi at an elevation of 600 m. at north latitude 21°40′ and east longitude 75°23′ and flows for a total length of 129 km. in a north-westerly direction to join the Narmada from the left, west of Barwani village. It drains a total area of 1,891 sq. km.

The Karjan rises in the Satpura range in Surat district of Gujarat, south of Nana village at an elevation of 300 m. at north latitude 21°23′ and east longitude 73°35′ and flows for a total length of 93 km. in a north-westerly direction to join the Narmada from the left, east of Sinor village. It drains a total area of 1,489 sq. km.

The Hiran rises in the Bhanrer range in the Jabalpur district of Madhya Pradesh near Kundam village at an elevation of 600 m. at north latitude 23°12′ and east longitude 80°27′ and flows in a generally south-westerly direction for a total length of 188 km. to join the Narmada from the right near Sankal village. The Hiran, the biggest right bank tributary of the Narmada, drains a total area of 4,792 sq. km.

The Tendoni rises in the Vindhya range in the Raisen district of Madhy Pradesh, east of Sodarpur village at an elevation of 600 m. at north latitude 23°22′ and east longitude 78°33′ and flows for a total length of 118 km. in a south-westerly direction to join the Narmada from the right, near Bhatgaon village. It drains a total area of 1,632 sq. km.

The Barna rises in the Vindhya range in the Raisen district of Madhya Pradesh, east of Barkhera village, at an elevation of 450 m. at north latitude 22°55′ and east longitude 77°44′ and flows for a total length of 105 km. in a south-easterly direction to join the Narmada from the right, near Dimaria village. It drains a total area of 1,787 sq. km.

The Kolar rises in the Vindhya range in the Sehore district of Madhya Pradesh, near Bilqisganj village at an elevation of 450 m. at north latitude 23°7′ and east longitude 77°17′ and flows for a total length of 101 km. in a south-westerly direction to join the Narmada from the right, south of Nasrullahganj. The Kolar drains a total area of 1,347 sq. km.

The Man rises in the Vindhya range in the Dhar district of Madhya Pradesh near Dhar town at an elevation of 500 m. at north latitude 22°33′ and east longitude 75°18′ and flows for a total length of 89 km. in a southerly direction to join the Narmada from the right, north of Talwara Deb village. It drains a total area of 1,528 sq. km.

The Uri rises in the Vindhya range in the Jhabua district of Madhya Pradesh, near Kalmore at an elevation of 450 m. at north latitude 22°36′ and east longitude 74°47′ and flows for a total length of 74 km. in a southerly direction to join the Narmada from the right, near Nisarpur. It drains a total area of 1,813 sq. km.

The Hatni rises in the Vindhya range in the Jhabua district of Madhya Pradesh, east of Kanas at an elevation of 450 m., at north latitude 22°32′ and east longitude 74°40′ and flows for a total length of 81 km. in a southerly direction to join the Narmada from the right, near Kakrana. It drains a total area of 1,943 sq. km.

The Orsang rises in the Vindhya range of the Jhabua district of Madhya Pradesh, near Bhabra village at an elevation of 300 m., at north latitude 22°30′ and east longitude 74°18′ and flows for a total length of 101 km. in a south-westerly direction to join the Narmada from the right, near Chandod. It drains a total area of 4,079 sq. km. and is next in size to the Hiran, amongst the right bank tributaries.

14.5 The details of the confluences of the various tributaries with the Narmada are given in Table 14.2.

CLIMATE

14.6 The Tropic of Cancer crosses the Narmada basin in the upper plains area and a major part of the basin lies just below this line. The climate of the basin is humid and tropical, although at places extremes of heat and cold are often encountered.

In the year, four distinct seasons occur in the basin. They are (i) cold weather, (ii) hot weather, (iii) south-west monsoon and (iv) post-monsoon.

Table 14.2

List of Major Tributaries of Narmada

Name of Tributary	Distance of confluence with Narmada from source (km.)
Right Bank	
1. Hiran	464
2. Tendoni	602
3. Barna	605
4. Kolar	747
5. Man	998
6. Uri	1035
7. Hatni	1075
8. Orsang	1191
Left Bank	
1. Burhner	248
2. Banjar	287
3. Sher	497
4. Shakkar	546
5. Dudhi	575
6. Tawa	676
7. Ganjal	757
8. Chhota Tawa	829
9. Kundi	943
10. Goi	1038
11. Karjan	1199

The cold weather season which commences in December and continues till the end of February, is characterised by bright cloudless days and clean nights and piercing winds. Frost is known to occur occasionally; hail too is not uncommon. There is slight precipitation in the basin during this season.

The hot weather starts in March and continues up to the middle of June. May is usually the hottest month. This season is generally dry except for occasional thunder-storms.

The south-west monsoon sets in by the middle of June and withdraws by the first week of October. June to September are the rainiest months. During this season, the weather is somewhat sultry and oppressive, especially in areas adjoining the Narmada river.

In the post-monsoon season, a few thunder-storms occur, especially in October. Thereafter, the weather clears up and dry pleasant weather prevails throughout the valley.

Rainfall

14.7 According to the records maintained by the India Meteorological Department, there were ten rain-gauges in 1867 in the entire Narmada basin. The number rose to 21 rain-gauges in the year 1891, the year from which published rainfall data are available. Thereafter, there has been a steady growth of the rain-gauge network in the basin. The number of reporting rain-gauges now functioning is 82. In addition to the reporting rain-guage stations, there are also a number of non-reporting rain-guages inside the basin. The data for these non-reporting stations are not being printed and issued by the IMD.

The normal annual rainfall for the basin works out to 1,178 mm. Nearly 90 per cent of this rainfall is received during the five monsoon months from June to October. About 60 per cent is received in the two months of July and August. The monthly distribution of normal rainfall over the entire basin has been broadly calculated as below:

Table 14.3

Monthly Distribution of Normal Rainfall

Month	Rainfall (mm.)	Percentage of annual rainfall
June	152.4	12.97
July	392.4	32.84
August	314.8	26.93
September	199.7	16.77
October	40.6	3.49
Dry months	78.1	7.00

The rainfall is heavy in the upper hilly and upper plains areas of the basin. It gradually decreases towards the lower plains and the lower hilly areas and again increases towards the coast and south-western portions of the basin. The monthly and annual normals of rainfall in the districts lying in the basin are shown in Table 14.4.

Temperature

14.8 In the cold weather, the mean annual temperature varies from 17.5°C to 20°C and in the hot weather from 30°C to 32.5°C. In the south-west monsoon, the temperature ranges from 27.5°C to 30°C. In the post-monsoon season, temperatures between 25°C to 27.5°C are experienced. The maximum and minimum temperatures for a few representative towns in the Narmada basin are given below, which clearly indicate the extent of variations:

Table 14.5

Maximum and Minimum Temperature

(Degree Centrigrade)

Sl. No.	Station	Jan.-March Max.	Jan.-March Min.	April-June Max.	April-June Min.	July-Sep. Max.	July-Sep. Min.	Oct.-Dec. Max.	Oct.-Dec. Min.
1.	Mandla	34.9	9.0	40.2	19.6	29.1	21.7	29.4	6.8
2.	Jabalpur	36.2	10.1	42.1	21.0	30.6	23.1	30.5	7.7
3.	Hoshangabad	37.4	11.6	41.6	24.5	30.5	23.0	30.1	11.0
4.	Khandwa	38.0	11.8	41.5	24.3	30.5	22.6	31.3	11.1
5.	Punasa	38.8	11.9	42.9	24.2	31.1	22.9	33.1*	12.0*

*Figures for 1960.

Evaporation

14.9 No data on evaporation is available in the basin. There are neither departmental nor agro-meteorological observatories of the IMD located in the basin.

The evaporation losses assumed in the various reservoir projects in the basin are as under:

Table 14.6

Monthly Evaportion Losses

Sl No.	Name of the project	Evaporation (Cms.) Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1.	Barna*	10	13	23	35	41	25	10	8	10	15	13	10	213
2.	Tawa**	12	12	15	22	31	25	9	9	12	12	12	12	183

*Barna Irrigation Project, Central Water and Power Commission (1958).
**Tawa Irrigation Project, Government of Madhya Pradesh (1970).

Table 14.4

Monthly and Annual Normal Rainfall in the Narmada Basin

Sl. No.	State/ District	Month-wise Normal Rainfall in mm.												Annual normal rain-fall in mm.
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Madhya Pradesh													
1.	Shahdol	39.9	35.7	24.2	18.8	15.1	185.3	387.3	393.6	217.5	54.5	17.5	7.4	1,396.8
2.	Mandla	27.8	34.7	24.5	17.2	16.4	196.2	492.7	447.8	226.5	59.7	18.4	7.7	1,569.6
3.	Durg	13.5	27.5	16.6	18.3	16.4	200.5	355.5	333.3	206.9	63.7	13.5	4.4	1,270.1
4.	Balaghat	17.8	29.6	18.5	16.2	11.8	211.7	557.9	445.2	232.6	62.7	13.3	5.9	1,623.2
5.	Seoni	24.2	32.5	24.4	18.9	16.7	195.0	429.2	350.2	204.7	58.6	19.8	10.3	1,384.5
6.	Jabalpur	26.4	23.3	13.2	6.2	6.9	135.7	424.2	380.0	190.8	42.7	15.7	9.0	1,274.1
7.	Narsimhapur	15.9	17.3	12.1	6.5	10.9	148.3	421.2	385.0	216.5	40.8	17.6	8.7	1,300.8
8.	Sagar	23.9	14.6	10.6	5.3	8.1	130.8	421.5	371.0	189.5	29.8	21.0	8.9	1,235.0
9.	Damoh	20.4	13.8	11.8	5.8	8.5	124.2	400.0	382.3	196.7	36.1	16.3	8.6	1,224.5
10.	Chhindwara	20.2	28.3	20.8	14.8	16.4	187.1	418.7	326.3	200.6	60.9	20.3	9.6	1,324.0
11.	Hoshangabad	14.1	9.4	7.2	2.5	9.9	156.2	439.5	361.7	230.3	34.0	21.3	8.4	1.294.5
12.	Betul	17.7	17.1	15.6	8.0	13.1	154.7	336.4	258.7	175.5	50.5	28.5	8.1	1,083.9
13.	Raisen	22.4	11.1	8.5	3.3	7.9	159.2	473.3	371.1	214.1	29.9	21.6	8.0	1,330.4
14.	Sehore	14.1	5.1	5.3	1.9	9.9	150.8	462.1	331.9	208.1	30.4	18.1	7.1	1,244.8
15.	East Nimar	8.8	5.3	4.0	1.5	9.3	138.2	282.6	196.6	168.7	33.9	23.0	8.1	880.0
16.	West Nimar	2.5	1.7	2.9	1.7	8.4	133.1	265.3	183.8	170.5	37.1	19.4	5.1	831.5
17.	Dewas	9.2	3.7	3.2	2.4	12.4	150.7	362.2	291.6	190.6	27.1	25.0	5.1	1,083.2

Table 14.4—Contd.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
18.	Indore	5.6	2.2	2.5	2.0	12.1	149.3	311.9	239.5	191.9	36.3	20.8	5.9	980.0
19.	Dhar	4.0	0.9	1.1	1.4	9.8	127.4	255.5	204.0	176.1	31.3	17.9	3.7	833.1
20.	Jhabua	4.5	1.9	1.5	0.7	9.1	116.3	283.3	211.5	162.3	25.5	9.5	1.9	828.0
Maharashtra														
21.	Dhulia	6.1	2.0	1.9	2.0	8.5	120.4	211.2	133.3	131.1	34.7	17.3	5.5	674.0
Gujarat														
22.	Baroda	2.0	2.5	0.8	3.2	4.8	123.3	389.6	233.8	170.1	28.2	9.1	1.4	968.8
23.	Broach	3.2	1.6	0.8	3.5	4.2	137.6	368.4	209.5	176.5	32.5	10.6	1.3	949.7
24.	Surat	3.2	2.0	0.9	2.5	6.7	240.9	634.1	344.8	229.6	42.4	12.3	1.8	15,21.2
25.	Panchamahals	2.9	2.0	1.7	1.7	8.2	123.2	377.5	266.7	175.1	20.3	7.3	1.4	988.0

Source: Memoirs of the India Meteorological Department, Vol. XXXI, Part III.

SOILS

14.10 No systematic soil survey of the entire Narmada basin has been carried out so far. Reconnaissance soil surveys have been made by the Central Water and Power Commission in connection with the investigation of the Bargi, Punasa, Barna and Tawa projects. These surveys and the general data regarding the soils of India indicate that the Narmada Basin consists mainly of black soils. The coastal plains in Gujarat are composed of alluvial clays with a layer of black soils on the surface.

14.11 The principal soil types found in the various districts lying in the Narmada basin are shown below:*

Table 14.7

Soils in the Narmada Basin Districtwise

Sl. No.	Name of the State/District	Type of soils
1	2	3
	Madhya Pradesh	
1.	Shahdol	Red, yellow, mixed red and black and medium black.
2.	Mandla	Red, yellow, shallow black and skeletal.
3.	Durg	Red loamy, red and yellow
4.	Balaghat	Red loamy, red, yellow and shallow black
5.	Seoni	Shallow black and skeletal
6.	Jabalpur	Medium and deep black and skeletal
7.	Narasimhapur	Deep black and skeletal
8.	Sagar	Medium black
9.	Damoh	Medium and deep black and mixed red and black
10.	Chhindwara	Shallow black and skeletal
11.	Hoshangabad	Medium and deep black and skeletal
12.	Betul	Shallow and medium black and skeletal
13.	Raisen	Medium and deep black
14.	Sehore	Medium black
15.	East Nimar (Khandwa)	Medium black
16.	West Nimar (Khargone)	Medium black
17.	Dewas	Medium black
18.	Indore	Medium black
19.	Dhar	Medium black
20.	Jhabua	Medium black

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*Soils of India by S. P. Raychaudhuri, R. R. Aggarwal, N. R. Datta Biswas, S. P. Gupta and P. K. Thomas.

Table 14.7—Contd.

1	2	3
Maharashtra		
21.	Dhulia	Medium and deep black
Gujarat		
22.	Baroda	Medium and deep black and grey brown
23.	Broach	Medium and deep black and coastal alluvium
24.	Surat	Medium and deep black and coastal alluvium
25.	Panchmahals	Medium black and grey brown

LAND USE AND AGRICULTURAL PRACTICES

14.12 State-wise land use details in the basin in 1967–68, the latest year for which the statistics are available, are shown below:

Table 14.8

Land Use Details in the Narmada Basin

(Thousand hectares)

Sl. No.	Item	Name of State			Total
		Madhya Pradesh	Maha-rashtra	Gujarat	
1.	Gross area	8,586	154	1,140	9,880
2.	Reporting area	8,584	154	1,129	9,867
3.	Area under forests	2,937	69	161	3,167
4.	Area not available for cultivation	663	5	131	799
5.	Culturable area	4,984	80	837	5,901
6.	Uncultivated culturable area	1,303	—	99	1,402
7.	Net area sown	3,681	80	738	4,499
8.	Area sown more than once	241	7	15	263
9.	Total cropped area	3,922	87	753	4,762
10.	Net area irrigated	130.3	5.2	66.8	202.3
11.	Gross area irrigated	132.4	7.9	73.2	213.5
12.	Percentage of net area sown to culturable area	73.9	100.0	88.2	76.1
13.	Percentage of net area irrigated to culturable area	2.6	6.5	8.0	3.4
14.	Percentage of net area irrigated to net sown area	3.5	9.9	9.9	4.5

14.13 The culturable area in the basin is about 3.02% of the total culturable area of India. The total cropped area in the basin forms 2.92% of the total cropped area in the country. The area under irrigated crops is about 4.47% of the cropped area in the basin. The general pattern, State-wise is as under:

Madhya Pradesh

Of the gross irrigated area of nearly 132,400 hectares, 31.4% is under rice, 36.5% under wheat, 5.2% under sugarcane, 4.4% under gram, 0.8% under cotton and the rest under other crops. The other irrigated crops are jowar, bajra, maize, barley, pulses, fruits, vegetables, linseed, rape, mustard, tobacco and fodder crops. Food and non-food crops cover about 98.3% and 1.7% of the irrigated cropped area respectively.

Maharashtra

Of the gross irrigated area of 7,900 hectares, 51.9% is under wheat, 6.3% under rice, 2.5% under sugarcane, 5.1% under cotton, 1.3% under grain and the rest under other crops. The other irrigated crops are jowar, bajra, maize, pulses, condiments, spices, groundnut, sesamum, tobacco and fodder crops. Food and non-food crops cover about 88.6% and 11.4% of the irrigated cropped area respectively.

Gujarat

Of the gross irrigated area of 73,200 hectares, 49.8% is under cotton, 11.3% under rice, 10.7% under wheat, 0.4% under sugarcane and the rest under other crops. The other irrigated crops are jowar, bajra, maize, barley, condiments, spices, rape, mustard, fruits, vegetables, tobacco and fodder crops. Food and non-food crops cover about 37.8% and 62.2% of the irrigated area respectively.

Summing up, of the total irrigated area in the basin, nearly 23.6% is under rice, 28.1% under wheat, 17.7% under cotton, 3.5% under sugarcane, 2.8% under gram and the rest under other miscellaneous crops. Food and non-food crops cover about 77.2% and 22.8% of the irrigated area respectively.

14.14 From the agricultural point of view, the seasons are (i) the kharif or monsoon (15th June to 14th October), the rabi or cold weather (15th October to 14th February) and the hot weather or summer season (15th February to 14th June). Wherever irrigation facilities exist, perennial and eight-monthly crops are cultivated. Cultivation is by a system of rotation of crops and the major crop seasons are the kharif and the rabi.

The sowing and harvesting seasons of the principal crops in the various States are shown below:

Table 14.9

Sowing and harvesping seasous

Name of crop	Period of	
	Sowing	Harvesting
(1)	(2)	(3)
Madhya Pradesh		
Rice (Autumn)	June-August	September-December
Wheat	October-November	February-April
Gram	September-November	February-March
Barley	October-November	February-April
Jowar (kharif)	June-July	October-December
Bajra	June-August	October-December
Sugarcane	December-January	November-March
Cotton	June-July	November-February
Groundnut	June-July	September-December
Maharashtra		
Wheat	October-November	March-April
Gram	October-November	February-March
Jowar (kharif)	June-July	November-December
Jowar (rabi)	September-October	January-February
Bajra	June-July	October-November
Maize	June-July	September-October
Cotton	June-September	February-March
Groundnut	June-July	September-December
Sesamum	June-July	September-October
Gujarat		
Rice (autumn)	June-July	October-November
Wheat	November	February
Gram	October-November	February-March
Jowar (kharif)	June-August	October-February
Jowar (rabi)	September-October	December-February
Bajra	June-July	September-October
Maize	June-July	September-October
Sugarcane	October-January	December-March
Cotton	June-July	December-April

Source: Indian Crop Calendar, 1967.

REGIONAL ECONOMY

Population

14.15 On the basis of the 1971 Census* and the percentage of the area of each district lying within the basin to the district as a whole, the total population in the basin is about 10.60 million. The State-wise distribution is as under:

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*Census Paper I of 1971 (supplement), Registrar General, India.

Table 14.10

Population in the Narmada Basin

State	Population (Millions)
1	2
Madhya Pradesh	8.07
Maharashtra	0.20
Gujarat	2.33
Total	10.60

Jabalpur is the only city in the basin with a population of more than one lakh. The average density of population in the basin is 107 persons per sq. km. against the figure of 182 for India as a whole. The density varies from region to region. The most densely populated district of Baroda has 254 persons per sq. km. while the districts of Raisen and Mandla have 66 persons per sq. km. Of the total population in the basin, nearly 81% live in the rural areas while the balance 19% live in urban areas. The working force constitutes nearly 36% of the total population. 42.9% of the working force are cultivators and 26.6% agricultural labourers. The remaining 30.5% of the working force is employed in manufacturing and other tertiary activities.

Forests & Agriculture

14.16 In the basin, forests occupy 32.1% of the total area and the culturable area 59.8%. Out of the total culturable area of 5.90 million hectares, nearly 4.76 million hectares are annually cultivated. 4.5% of the cultivated area is irrigated annually. Wheat is the most important irrigated crop in the basin covering nearly 28.1% of the total irrigated area.

Power

14.17 The hydroelectric power potential of the basin has been assessed by the CWPC as 2,027 MW at 60% load factor. At present, there are no major hydroelectric stations in the basin. The Tawa multi-purpose project, which will have an installed capacity of 42 MW is under construction. There are thermal stations at Jabalpur and Satpura. The details of the power projects under operation and construction are shown below:

Table 14.11

Power Projects in the Narmada Basin

Sl. No.	Name of the Station	Installed capacity (MW) Hydro	Thermal
1	2	3	4
1.	Tawa	42	—
2.	Jabalpur	—	12
3.	Satpura	—	312.5
	Total	42	324.5

The power generated is fed into the State grids.

Mineral Wealth

14.18 The principal mineral found in the basin are:*

Coal: In Chhindwara, Betul and Narsimhapur districts.

Iron ore: In Jabalpur, Durg, Sagar, Hoshangabad, East Nimar and West Nimar districts.

Bauxite: In Jabalpur, Jhabua, Chhindwara and Balaghat districts.

Manganese: In Balaghat, Chhindwara, Jhabua, Jabalpur, Indore and Baroda districts.

Limestone: In Jabalpur and Durg districts.

Fire Clay and China Clay: In Jabalpur, Chhindwara, Durg, Shahdol, Hoshangabad and Jhabua districts.

Talc and Soapstone: In Durg, Jabalpur and Jhabua districts.

Graphite: In Betul district.

Fluorspar: In Durg district.

Asbestos: In Jhabua district.

Felspar: In Jabalpur and Chhindwara districts.

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*Techno-Economic survey of Madhya Pradesh & Gujarat, NCAER.

Barytes: In Dewas, Jabalpur and Indore districts.
Lead: In Hoshangabad, Durg and Jabalpur districts.
Mica: In Balaghat and Chhindwara districts.
Copper: In Jabalpur district.

Industries

The important industries in the basin are as under:

Cotton textiles, silk and other fabrics in Broach.

Tobacco products, plywood and hard and soft boards, glass and ceramics, inks, paints and varnishes, drugs and pharmaceuticals in Jabalpur.

Agricultural equipment in Khandwa.

Machine tools in Khandwa and Jabalpur.

Communications

14.19 The basin is served by the Central, South-Eastern and Western Railways. The main Bombay-Baroda-Delhi line passes through its lower reaches. The Delhi-Nagpur-Madras line passes through the middle of the basin. The other important lines connecting different places in the basin are Itarsi-Khandwa, Bhopal-Ujjain, Khandwa-Ujjain, Harsi-Jabalpur, Jabalpur-Raipur etc. The National Highways connecting Delhi with Bombay and Hyderabad pass through the basin. Part of the National Highway connecting Varanasi with Nagpur also lies in the basin. In addition, there is a network of State Highways, district and village roads.

The Narmada is navigable in its lower reaches. The tidal influence is felt up to 48 km. upstream from the mouth of the river in the Gulf of Cambay. Broach is an important river port. Between the mouth of the Narmada and the city of Broach, fairly large sized barges ply for the transport of goods. For another 32 km. above Broach, navigation is possible in the sandy reach. Beyond this point, on account of rocky outcrops and rapids navigation is not possible. The tributaries of the Narmada are not navigable.

The basin is fairly well served with communications.

Dependence on Rainfall and Water Resources

14.20 The economy of the basin largely depends on agriculture, which, in view of the uneven incidence of the rainfall, provides a low level of subsistence. No major irrigation projects in the basin had been undertaken in the past. After Independence, the Tawa and the Barna projects were taken up and are still under construction. There is a demand for the development of water resources in the basin.

WATER RESOURCES

Surface Waters

14.21 The surface water potential of the Narmada river system has been assessed at different times by different authorities. The very first assessment was made by the first Indian Irrigation Commission taking the Narmada and Tapi river systems together. Since there were no records to show the surplus passing to the sea the calculations were based on the co-efficient of runoff, selected with regard to the rainfall and other conditions, and the co-efficient of actual flow, determined for other catchments. The Commission, however, cautioned that the estimates arrived at by this method must be regarded as mere rough approximations. According to their calculations the total annual surface flow in the Narmada and Tapi river systems together was estimated at 70,792 m. cu. m.*

In 1949 when the assessment of the basinwise water resources of the country was worked out on the basis of Khosla's formula, the annual runoff of the Narmada river system was estimated to be 49,241 m. cu. m.**

In 1960 when the irrigation potential studies of the country were made by the CWPC, the total annual runoff of the Narmada river system was assessed as 40,088 m. cu. m.†

In 1965, the Narmada Water Resources Development Committee, set up by the Government of India, reported the total annual runoff of the Narmada river system at Garudeshwar, below Navagam dam site as 44,331 m. cu. m.‡

14.22 Systematic gauge and discharge observations were started on the Narmada only in 1947 when the Central Waterways, Irrigation and Navigation Commission took up investigations for formulating flood control measures and assessing how much of the available water resources of the Narmada could be used for the development of irrigation, hydro-power, etc. The Commission opened discharge observation stations of the Narmada and its principal tributaries during the period 1948-51. These are listed in Table 14.12.

The above stations were confined to important sites on the main river and its tributaries. The work of discharge observations was handed over to the State Governments in 1953. The State Governments continued

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*Report of the Indian Irrigation Commission (1901-03), Part I.

**An appraisal of water resources by Dr. A. N. Khosla, UNESCO.

†Report of the technological possibilities of irrigation projects in India, Central Water & Power Commission (Unpublished).

‡Report of the Narmada Water Resources Development Committee (1965).

Table 14.12

Discharge Sites Set-up by CWINC

Sl. No.	Station	River	Year of establishing site	Purpose for which established
1	2	3	4	5
1.	Manote	Narmada	1948	To know the discharge for Bilghara Dam site
2.	Bargi	Narmada	1948	To know discharge at Bargi Dam site
3.	Jamtara Railway Bridge	Narmada	1949	To know the discharge below Bargi Dam site (Bargi discontinued)
4.	Punasa	Narmada	1951	To know the discharge for Punasa hydroelectric project
5.	Mortakka Rly. Bridge	Narmada	1948	-do-
6.	Khora Khada	Burhner	1949	To know the discharge of Burhner river
7.	Mohgaon	Burhner	1948	
8.	Dhudhi Rly. Bridge	Dhudhi	1950	For the Dhudhi project
9.	Bari	Barna	1949	To know the discharge of Barna for Bari irrigation project
10.	Tawa Dam site	Tawa	1949	To know the discharge of Tawa for Tawa irrigation project
11.	Garudeshwar	Narmada	1948	To know the discharge for Broach Irrigation Project

observations at Jamtara, Tawa, Mortakka and Garudeshwar sites but discontinued them at other places.

Subsequently, the State Governments of Madhya Pradesh and the erstwhile Bombay State set up a number of other gauge and discharge sites in order to prepare schemes for increasing food production. A list of gauge and discharge sites set up by the State Governments in the Narmada basin is given in Table 14.13.

So far as the main stem of the river is concerned, there are only three important observation sites, viz. Jamtara, Mortakka and Garudeshwar.

14.23 The data based on actual discharge observations covers a limited period. At the instance of the Narmada Water Resources Development Committee the CWPC worked out a runoff series based on the rainfall records of the Narmada basin, after working out a rainfall runoff relationship on the basis of the observed data for the period 1948 onwards. These studies were further recast on the basis of a zonal analysis. The zones considered were:

(i) Catchment area up to Jamtara;

Table 14.13

Gauge and Discharge Sites Set-up by States

Sl. No.	Site	River	Nature of observations	Observing Agency	Remarks
1	2	3	4	5	6
Madhya Pradesh					
1.	Sankalghat	Narmada	GD	Haran Irrigation Division	Data available from June, 1956 to date
2.	Hoshangabad	-do-	GD	Irrigation Dvn. Narasimhapur	Data available from July, 1963 to date
3.	Dharamrai	-do-	GD	Khargone Irrigation Dvn.	Observations started in 1960 by CW&PC. Taken over by Madhya Pradesh Govt. in June, 1962
4.	Lawakheri (Kolar Dam)	Kolar	GD	Irrigation Dvn., Bhopal	
5.	Surai Dabha	-do-	GD	-do-	Started in June, 1954
6.	Sukta Dam site	Sukta	GD	Sukta Irrigation Divn.	Started in July, 1954
7.	Barbaspur	Banjar	GD	—	Observations started in 1956 and continued
8.	Chipaghat	Hiran	G	Hiran Irrigation Dvn.	Data available from Sept. '55 to March '56. Site shifted to Pondi
9.	Pondi	-do-	GD	-do-	Data available from March, 1956 to date
10.	Dhorda Mohar	Tawa	G	Hiran Irrigation Dvn.	
11.	Chiddgam	Ganjal	G	-do-	
12.	Harda Khas	Anjal	G	Irrigation Dvn. Narasimhapur	
13.	Mandla	Machak	G	Sukta Irrigation Dvn.	Set up in June, 1956
14.	Asapur	Agni	G	Khargone Irrigation Dvn.	Data available from July, 1955
15.	Bhamgarh	Chhota Tawa	G	-do-	-do-
Gujarat					
1.	Broach	Narmada	G	Dy. Engineer, N.H. Sub-Dvn. Broach	Observations continued from 1887 to date
2.	Rajpipla	Karjan	GD	Narmada Irrigation Circle	Station was set up in 1954
3.	Jojwa	Orsang	G	Baroda Panchayat Dvn.	Observations taken on weir

Table 14.13—contd.

1	2	3	4	5	6
4.	Bodeli	-do-	GD	River Gauging Sub-Division	Observations continued from June, 1957 to date
5.	Wasna	Hiran	GD	Baroda Irrigation Dvn.	Observations continued from Sept., 1951 to date
6.	Amadra	Unch	GD	River Gauging Sub-Division	Observations continued from June, 1952 to Feb., 1955
7.	Kikawada	Sukhi	GD	-do-	Observations continued from June, 1957 to date

(ii) Catchment area of the Tawa river up to the Railway Bridge;

(iii) The area between Jamtara and Mortakka excluding the Tawa catchment up to the bridge site; and

(iv) The area between Mortakka and Garudeshwar.

Based on these studies, the runoff series for the years 1915–1962 have been worked out. The series for the Garudeshwar site is given in Appendix 14.1. It will be seen that the flow at Garudeshwar has been less than 24,669 m. cu. m. in 4 out of 48 years and less than 33,304 m. cu. m. in 8 out of 48 years. Even the years in which it has been less than 24,669 m. cu. m., this flow was preceded by a year of good run-off thereby indicating that with carry-over storage from the preceding year, the low run-off period could be easily tided over.

Based on the above studies of the CWPC, the runoffs at various sites, for different dependabilities, were also worked out by the Narmada Water Resources Development Committee. These are given below:*

Table 14.14

Run-off at various sites

Percentage dependability	Yield in m.cu.m.					
	Jamtara	Tawa	Punasa	Barwaha	Hiranphal	Navagam
1	2	3	4	5	6	7
50	10,756	4,502	35,561	38,447	42,210	44,331
75	8,240	3,170	28,654	31,010	34,007	35,672
90	5,970	1,961	22,425	24,324	26,631	27,864

Like the peninsular rivers of India, the Narmada rises in the latter half of June and the flow reaches its maximum in the months of August and September. Thereafter, it begins to fall in October and reaches its lowest level just before the monsoon. A maximum flow of 39,644 cumecs was recorded at Garudeshwar on the 17th of September, 1950 and a minimum of 10.3 cumecs on the 10th June, 1952.

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*Report of the Narmada Water Resources Development Committee (1965).

*Ground Water**

14.24 The Archaeans cover a major part of the Balaghat district and parts of Seoni, Chhindwara, Betul, Dewas and Jhabua districts. The Chhattisgarhs cover part of Durg district. The Vindhyans cover parts of Khargone, Khandwa, Dewas, Raisen, Sagar and Damoh districts. The Gondwanas partly cover Shahdol, Jabalpur, Chhindwara, Betul and Hoshangabad districts. Lametas and Bagh beds are not of much significance for the reason that they cover only small parts of Jabalpur, Khargone, Dhar and Jhabua districts; and comprise sandstones, mudstones, limestones and marls. Deccan traps cover a very extensive area in the form of basaltic flows, together with inter-trappean beds. They cover major parts of Mandla, Seoni, Chhindwara, Khandwa, Khargone, Dhar, Indore, Dewas and Sehore districts and small parts of Shahdol, Betul, Jhabua and Raisen districts. The quarternary deposits cover the river alluvia of Narmada, comprising parts of Hoshangabad, Sehore, Raisen, Narasimhapur and Jabalpur districts and shallow alluvial beds in the district of Damoh. These alluvial deposits comprise alternating beds of sands and clays along with soil cap and lateritic cover of local significance. These deposits are of great significance for their ground water potential.

In the upland alluvial part of the Narmada basin covering parts of Sehore, Hoshangabad, Raisen, Narasimhapur and Jabalpur districts, the alluvial materials varies in thickness from that of a sheet of paper to 565 m. It comprise clays, sands and gravel and occasionally pebbles and boulders deposited over the Deccan traps, either Vindhyans or Archaeans. The alluvial materials, particularly sands and gravels are the most important horizons for ground water development. Under exploratory and production well programmes, about 120 deep bore wells have been drilled in the alluvial areas. Ground water occurs in the alluvial materials under both water table and confined conditions. The water table is generally deep in areas adjacent to the foot of the Vindhyas and the Satpuras and also towards the Narmada and its tributaries. Perched water table conditions are noticed at certain places with occurrences of clay beds at shallower depths. Ground water occurring under confined conditions is tapped by dug-cum-bore wells and by shallow or deep tubewells. Recharge to the water table and also the confined aquifers of the alluvium, takes place mainly by direct precipitation. Considering the confined nature of the valley, the annual rainfall and the drainage pattern, the quantum of recharge to the water table and confined aquifers should be very high. Incipient seepage from nallas and major streams draining the recharge areas also form a significant source of recharge to ground water. The quality of ground water both in the water table and confined aquifers is quite suitable for irrigation purposes. In the following areas, promising aquifers have been proven after investigations:

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*Ground Water Resources of India, Status and Surveys, Prospects and Perspectives, Geological Survey of India (August, 1970).

(i) The Padghal area located to the south of the Narmada, in Hoshangabad district, covering 100 sq. km.
(ii) The Powerkheda-Ari-Babai area located to the south of the Narmada, in Hoshangabad district, covering 650 sq. km.
(iii) The Khapuria Kalan-Tonga area in Raisen district, lying north of the Narmada, and covering about 600 sq. km.
(iv) The Mahuakhera-Godarwara area lying in Hoshangabad and Narasimhapur districts, south of the Narmada, covering about 2,000 sq. km.
(v) The Dhobi-Kasikheri area lying in Narasimhapur district, north of the Narmada, and covering 120 sq. km.
(vi) The Shahpura-Bheraghat area in Jabalpur district, lying to the north of the Narmada, and covering 400 sq. km.

Ground water occurs both under water table and confined conditions in different trap flows in the basin. The Deccan lava flows are known as the Malwa traps and the development of ground water by means of dug wells and dug-cum-bore wells is considered possible in the following areas:

(i) An area of 80 sq. km. bounded by north latitudes 22°38′ and 22°42′ and east longitudes 75°41′ and 75°51′.
(ii) An area of 100 sq. km. bounded by north latitudes 22°36′ and 22°42′ and east longitudes 75°30′ and 75°37′.
(iii) Nearly 75 sq. km. area between north latitudes 22°52′ and 23°00′ and east longitudes 75°30′ and 75°34′.

14.25 Systematic ground water studies in the basin have been intensified recently for obtaining precise data on the seasonal fluctuation of the water table, estimate of aquifers and their parameters, the chemical quality of ground water and recharge-discharge relationship, etc. Under this programme, the drilling of observation wells and setting up permanent hydrographic stations are being undertaken.

The fertile Narmada valley has tremendous potentialities in ground water of excellent quality and there is great scope for the development and utilisation of this water for a variety of purposes.

EXISTING DEVELOPMENT

14.26 The first Indian Irrigation Commission had made the following remarks in respect of providing irrigation facilities in the Narmada basin:*

> "Canals from the Nerbudda and Tapti appear to us to be less urgently required as a measure of protection from famine, and great caution must be exercised in introducing canal irrigation in the black cotton soil tracts of Gujarat. A Nerbudda Canal in black soil could not possibly pay, or be justified except for the protection of the country in seasons of extreme drought."

14.27 Since the Narmada tract was not subject to any serious famines, the utilisation of its water resources had not in the past been given serious consideration. Moreover because the soil in the basin is generally retentive and capable of producing a fairly good harvest even in years of scanty rainfall any large-scale irrigation development in the basin had not been taken up seriously. This accounts for the absence of the major irrigation works like dams, barrages or anicuts across the Narmada or any of its tributaries. Only a few medium projects, with total irrigation potential of about 40,468 hectares, exist in the basin. The principal medium works and areas irrigated by them are shown below:

Table 14.15

Medium Works in Operation

Sl. No.	Name	Ultimate irrigation (Hectares)	Estimated Cost (Rs. million)
1	2	3	4
1.	Sampna Dam Project	2,200	4.88
2.	Dhukrikheda Dam Project	2,670	4.38
3.	Dhuandhar Project	1,330	4.59

14.28 The first major work to be undertaken in the Narmada basin was the Tawa Project across the river Tawa, a major tributary on the left bank of the Narmada, near Hoshangabad. It is a composite dam of earth and masonry 1,630.22 m. long with two dykes of 183 m. length each and of a maximum height of 57.95 m. The gross storage in the reservoir is designed to be 2,311 m. cu. m. of which the live storage will be 2,087

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*Report of the Indian Irrigation Commission (1901-03).

m. cu. m. There will be two canals, one on each bank. The left bank canal will be 120 km. and the right bank canal 76.85 km. long. The total irrigation is expected to be of the order of 331,854 hectares. The work on the dam is in progress. Work on the canals has also been started and the excavation and the construction of cross drainage works are in progress. The project it is claimed will be substantially completed towards the end of the Fourth Plan and provide irrigation to about 121,406 hectares in the first phase. The latest estimated cost of the work is Rs. 401.90 million, against the original estimates a sum of Rs. 115.64 million had been spent to end of June, 1970.

The progress on this work has been slow and although ten years have elapsed since the construction started, the dam is only in the foundation stage and the canal partially completed.

14.29 Two other projects, the Barna Project and the Chandrakesher Project have been sanctioned in Madhya Pradesh. The Barna Project envisages the construction of a masonry dam across the river Barna in Raisen district. It is 432 m. long and 47.7 m. high at the deepest section. The reservoir will have a gross storage of 493.40 m. cu. m. and a live storage of 407.00 m. cu. m. The main canal will be 38 km. long and it will irrigate 60,290 hectares. At present, work on the main dam as well as the canal system is in progress. The Barna project is estimated to cost Rs. 70 million, of which a sum of Rs. 17.56 million has been spent to end of March, 1970 and it is expected to be completed towards the end of Fourth Plan.

14.30 In Gujarat, the Broach Irrigation Project had been sanctioned in the year 1960. It comprised the construction of a dam with F.R.L. plus 162 at Navagam to irrigate 3.9 lakh hectares in the Broach and Baroda districts of the Gujarat State. The project also envisaged the subsequent raising of the dam and together construction of a high level canal to irrigate larger areas. Work on this project was inaugurated on the 5th April, 1961. All the preliminary works connected with this project, such as approach roads, colonies, workshops, etc. have been completed. Meanwhile a study carried out by the Gujarat Government showed that the construction of a higher dam at this site would enable the State to realise greater benefits. Accordingly, the Gujarat Govt., in August, 1963 proposed the height of the Navagam dam should be raised to F.R.L. plus 425. It provided for the construction of a high level canal taking off from Navagam with F.S.L. plus 300 and irrigating 1.6 million hectares. The scheme also included the reclamation of the little Rann of Kutch, and irrigation of 364,212 hectares there. This proposal involved the submersion of two dam sites in Madhya Pradesh and Maharashtra reaches, viz.

Hiranphal and Jalsindhi and an inter-State Agreement was called for. In November, 1963, the States reached a tentative agreement, but it was not ratified. Further efforts to resolve the difference by mutual discussions also failed. In 1954, the Government of India, set up the Narmada Water Resources Development Committee with Dr. A. N. Khosla as its Chairman. After a year's detailed study, the Committee submitted a report recommending the optimum utilisation of the Narmada waters and their allocation between the different States.

14.31 The Master Plan on the utilisation of the Narmada waters was sumbitted to Khosla Committee by the Madhya Pradesh Government. It envisaged the construction of 19 dams on the Narmada and its tributaries and the irrigation of 3.1 million hectares utilising 29,295 m. cu. m. of water.

14.32 The Gujarat Government also submitted to the Khosla Committee a revised proposal for the construction of the Navagam dam, which included the construction of the Navagam dam to a height of F.R.L. plus 490 and the extension of irrigation to the Great Rann of Kutch. The requirements of water were indicated as 21,648 m. cu. m. to irrigate a total area of 1.89 million hectares.

14.33 The Rajasthan State, whose desert areas in Barmer and Jalore districts adjoin the tail reaches of the high level Narmada Canal of Gujarat, requested the Committee to allocate the Narmada waters for irrigating more than 0.4 million hectares in their territory.

14.34 The Maharashtra State urged upon the Committee that the State had vital interests in the development of the hydro-power of the Narmada in the common reach with Madhya Pradesh and that Gujarat could extend irrigation to her areas by taking the canal at the low level of plus 190.

14.35 The Narmada Water Resources Development Committee recommended that the best plan to utilise the Narmada waters would be to build 12 dams in Madhya Pradesh and the Navagam dam in Gujarat with F.R.L. plus 500. They suggested the following allocation of the Narmada waters: *

State	*m. cu. m.*
Madhya Pradesh	19,242.3
Gujarat	13,136.6

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*Report of the Narmada Water Resources Development Committee (1965).

State	*m. cu. m.*
Maharashtra	123.3
Rajasthan	308.4
Total	32,810.6

14.36 The Committee also made recommendations regarding the sharing of costs and benefits. The States of Gujarat and Rajasthan accepted the recommendations of the Committee, but Madhya Pradesh and Maharashtra rejected them. Further efforts by the Central Government to bring about an agreed solution of the problem were unsuccessful. Therefore, the Gujarat State requested the Central Government to appoint a tribunal for the adjudication of the dispute under the Inter-State Water Disputes Act, 1956. The Central Government constituted a Tribunal in October, 1969. The dispute is now pending before the Tribunal.

14.37 Some particulars of important major and medium projects under operation or under construction in the Narmada basin are given in Appendices 14.2 and 14.3.

14.38 There are also minor schemes largely comprising wells and a few tanks, for irrigating a sizable area. The details of the area irrigated by various sources like canals, tanks, wells, etc. during the year 1967–68 in the basin are shown below:

Table 14.16

Source-wise Irrigation

Sl. No.	Source of irrigation	Area irrigated ('000 hectares)			
		Madhya Pradesh	Maha-rashtra	Gujarat	Total
1	2	3	4	5	6
1.	Canals	34.9	1.0	4.4	40.3
2.	Tanks	15.9	Neg.	4.6	20.5
3.	Wells	73.7	4.2	55.2	133.1
4.	Other sources	5.8	Neg.	2.6	8.4
	Total	130.3	5.2	66.8	202.3

By the end of 1968–69, the area under minor schemes had increased by about 21,010 hectares.

14.39 The annual diversions and utilisation by the major and medium projects under operation and construction as in 1968–69 in the basin (excluding the Navagam Dam Project) according to the data supplied by the concerned States total 1,841 m. cu. m.

As regards the statistics of the minor schemes in operation and under construction in 1968–69, no information is available. Based on the area irrigated from these sources and on rough duties, an approximate estimate of the quantity of water diverted for irrigation comes to 1,673 m. cu. m.

Reservoir Losses

14.40 On the basis of assumptions detailed in para 1.33 the reservoir losses from the various schemes in the basin will be as under:

(i) Major and Medium Schemes	366 m. cu. m.
(ii) Minor Schemes (tanks)	278 m. cu. m.
Total	644 m. cu. m.

14.41 Thus, on completion and full development the major, medium and minor projects in operation and under construction in 1968–69 would use about 4,158 m. cu. m. (including reservoir losses) of which 2,786 m. cu. m. is surface waters and 1,372 m. cu. m. is ground waters.

14.42 There are a number of industries located in the basin, around Jabalpur, Khandwa and Broach. The data on present industrial water needs is not readily available. Such needs are expected to grow. The problem of water pollution in the basin due to the discharge of industrial wastes has not been reported to be serious. However, the problem may arise in future, and will have to be guarded against.

FUTURE DEVELOPMENT

14.43 One major and two medium projects are proposed to be taken up for construction in the Fourth Plan Period. There are no new projects for construction in the basin in Maharashtra and Gujarat States during the Fourth Plan. Appendix 14.4 shows the salient features of these projects.

The Bargi project, which is a major project, is described briefly in the following paras.

Bargi Project

14.44 The project provides for the construction of a dam across the Narmada near village Bijora, about 43.2 km. from Jabalpur. The dam will be 5,680 m. long, of which 960 m. will be in masonry and the rest of earth. The reservoir created behind the dam will have a gross storage capacity of 3,922 m. cu. m., of which 3,182 m. cu. m. will be live storage and the balance 740 m. cu. m. dead storage. A network of canals, 135.06 km. long on the left bank and 139.22 km. on the right bank, will irrigate annually 267,000 hectares in Jabalpur and Narasimhapur districts at an estimated cost of Rs. 640.00 million.

14.45 On completion and full development, the Fourth Plan projects will utilise about 4,778 m. cu. m. of Narmada waters including reservoir losses.

By the end of the Fourth Plan, the area under minor schemes is expected to increase by about 152,320 hectares requiring nearly 1,624 m. cu. m. of waters including reservoir losses.

Thus, the additional utilisation by the Fourth Plan major, medium and minor projects would be of the order of 6,402 m. cu. m. benefiting an area of 424,990 hectares.

On the full development of Fourth Plan projects (excluding the Navagam project), a total quantity of 10,560 m. cu. m. of waters (8,046 m. cu. m. of surface waters +2,514 m. cu. m. of ground waters) would have been used for irrigating a total area of 1,021,060 hectares.

After completion and full development of the Fourth Plan projects (excluding the Navagam project) there would still be a large quantity of water available in the river for utilisation by future projects. Several new schemes have been proposed in the basin. The names of the new major and medium projects proposed by Madhya Pradesh State are given in Appendix 14.5.

FLOODS, WATERLOGGING AND DRAINAGE

14.46 The Narmada in Madhya Pradesh flows in a deep channel with high banks, which are rarely over-topped even in exceptional floods. Floods, therefore, do not present any serious problem in the State and for this reason flood control works have not been undertaken.

Below the Hiranphal-Navagam gorge, the Narmada spreads out over the flat Gujarat plains and flows as a wide stream with low banks for the rest of its course down to the Gulf of Cambay. Serious floods occur once in five to six years in this reach and cause damage to life and property. During the last fifty years, such floods have occurred in 1921, 1926, 1927, 1928, 1934, 1935, 1942, 1944, 1950, 1954 and 1961. The flood of July, 1927 is reported to have been the highest ever recorded. The maximum discharge recorded at Garudeshwar on the 17th September, 1950 was of the order of 39,644 cumecs.

Besides damaging crops and flooding villages above and below Broach, floods affect the City of Broach covering areas to the depth of several metres. Most of the trouble is on the left bank of the river and the damage is greatly aggravated if a high flood synchronises with a high tide from the sea. A number of dams have been proposed by the various State Governments on the main Narmada and its tributaries. With proper co-ordination regulating the various reservoirs, it is expected that there will be considerable flood moderation and partial flood protection to Broach and areas below it.

14.47 Waterlogging occurs in the low lying coastal areas in Broach district due to defective drainage. Waterlogging in the areas under the irrigated commands in the basin has not been reported thus far as there is very little perennial irrigation. Drainage and salinity control measures are needed in the coastal areas, in Broach district.

SOIL CONSERVATION

14.48 The problem of soil erosion is fairly acute in the upper hilly and upper plains regions in the Narmada basin. Acute erosion also occurs close to the river in a long stretch of the lower plains. Otherwise, in the lower plains and lower hilly areas, soil erosion is of medium intensity. Soil erosion is mainly due to large-scale unplanned felling and thinning of trees, uncontrolled grazing and failure to replant trees. Erosion is also accelerated because of certain faulty agricultural practices like ploughing through the contours of unbunded fields.

For the conservation of river supplies and especially of the storage capacities created in the reservoirs, it is important that soil conservation measures are taken up both in the cultivated areas and culturable but not cultivated areas of the basin and in the areas under forests. Soil conservation measures may take the shape of afforestation in new areas and upgrading of existing forests, terracing and contour bunding on agricultural lands, pasture development, stream control measures and silt clearance works.

GENERAL

14.49 The Narmada and its tributaries form an inter-State river system flowing through the States of Madhya Pradesh, Maharashtra and

Gujarat. The concerned States have not been able to arrive at an agreement with regard to the sharing of the water resources of the basin. Efforts made by the Central Government to bring about an agreement on the allocation of the Narmada waters have not been successful. In October, 1969, a Tribunal was constituted under the Inter-State Water Disputes Act to determine the allocation of waters of the Narmada and the height to which the Navagam dam should be built. The dispute is now pending before the Tribunal.

14.50 A network of evaporation measuring stations in the basin, particularly at the sites of existing and proposed reservoirs should be established.

14.51 Gauge and discharge observations at the various sites should be continued on a permanent basis, to obtain data essential not only for the preparation of individual projects but also for the regulation, to the best advantage of available river water.

14.52 Further systematic and scientific exploratory work is needed for a quantitative and qualitative assessment of the ground water resources in the basin, so that these resources can be exploited in a rational way, either independently or in conjunction with surface waters.

14.53 There is need for inter-State co-operation and agreement in respect of carrying out soil conservation measures and conserving the storage capacities of existing and proposed reservoirs in the basin.

14.54 It is necessary for systematic data to be collected of the sediment carried by the rivers, which would be of considerable use in working out the lives of reservoirs. It would also reflect the effect of soil conservation works carried out in the basin.

SALIENT FEATURES OF THE MAHI BASIN

(i) Source: Near village Sardarpur in Dhar district of Madhya Pradesh (Latitude 22°35′N, Longitude 74°58′E)

		Km.	Miles
(ii) Length of Mahi river			
in Madhya Pradesh		167	104
in Rajasthan		174	108
in Gujarat		242	150
Total		583	362
		Sq. Km.	Sq. miles
(iii) Drainage area			
Madhya Pradesh		6,695	2,585
Rajasthan		16,453	6,352
Gujarat		11,694	4,515
Total		34,842	13,452
(iv) Population (1971 Census)	5.03 millions.		
(v) Density of Population	144 per sq. Km.	373 per sq. mile	
		Cumecs	Cusecs
(vi) Maximum discharge at railway bridge near Vasad 484 km. (301 miles) from source in 1919		29,705	1,049,000
(vii) Minimum discharge at Wanakbori weir 428 km. (266 miles) from source		1.4	50
(viii) Annual runoff at Kadana, 357 km. (232 miles) from source		m.cu.m.	MAF
(a) @ 50% dependability		7,702	6.24
(b) @ 75% ,,		4,361	3.54
(c) @ 90% ,,		2,124	1.72
(ix) Maximum annual runoff (computed at Kadana in 1944)		24,067	19.51
(x) Minimum annual runoff (computed) at Kadana in 1899		538	0.44
		Thousand hectares	Thousand acres
(xi) Culturable area (1967-68)		2,210	5,461
(xii) Net area sown (1967-68)		1,598	3,949
(xiii) Gross area sown (1967-68)		1,799	4,446
(xiv) Net area irrigated (1967-68)		135	334
(xv) Gross area irrigated (1967-68)		148	366
(xvi) Area irrigated after completion and full development of Fourth Plan projects		531	1,312
(xvii) Probable additional irrigation by future projects		N.A.	
(xviii) Water utilisation including reservoir losses		m. cu. m.	MAF

(a) On completion and full development of major, medium and minor projects under operation and construction at the end of 1968-69	Surface water	3,830	3.10
	Ground water	1,083	0.88
	Total	4,913	3.98
(b) On completion and full development of Fourth Plan projects	Surface water	6,654	5.39
	Ground water	1,500	1.26
	Total	8,204	6.65

SALIENT FEATURES OF THE DHADHAR BASIN

(i) Source: Near Ghanta village in Panchmahals district of Gujarat (Latitude 22°30′N Longitude 73°35′E).

(ii)	Length of Dhadhar river	135 km.	84 miles
(iii)	Drainage area	2,770 sq. km.	1,069 sq. miles
(iv)	Population (1971 Census)	0.58 million	
(v)	Density of population	210 per sq. km.	544 per sq. mile
(vi)	Maximum discharge	N.A.	
(vii)	Minimum discharge	N.A.	
(viii)	Average annual runoff (whole basin)	704 m. cu. m.	0.57 MAF
(ix)	Maximum annual runoff observed to date	N.A.	
(x)	Minimum annual runoff observed to date	N.A.	

			Thousand Hectares	Thousand acres
(xi)	Culturable area (1967-68)		201	497
(xii)	Net area sown (1967-68)		174	429
(xiii)	Gross area sown (1967-68)		182	450
(xiv)	Net area irrigated (1967-68)		14	35
(xv)	Gross area irrigated (1967-68)		15	37
(xvi)	Water utilisation including reservoir losses		m. cu. m.	MAF
	(a) From projects under operation & construction at the end of 1968-69	Surface water	41	0.03
		Ground water	130	0.11
		Total	171	0.14
	(b) On completion & full development of Fourth Plan projects	Surface water	60	0.05
		Ground water	191	0.15
		Total	251	0.20

CHAPTER XV

THE MAHI BASIN

The Mahi basin extends over an area of 34,842 sq. km. and lies between east longitudes 72°15′ and 78°15′ and north latitudes 22°0′ and 22°40′. Located in Western India, the basin covers areas in the States of Madhya Pradesh, Rajasthan and Gujarat. The State-wise distribution of the drainage basin is given below:

Table 15.1

Drainage Area of the Mahi Basin

State	Drainage area Sq. km.
1	2
Madhya Pradesh	6,695
Rajasthan	16,453
Gujarat	11,694
Total	34,842

15.2 The basin is bounded on the north and north-west by the Aravalli hills, on the east by the ridge separating it from the Chambal basin, on the south by the Vindhyas and on the west by the Gulf of Cambay. The basin has a maximum length of about 330 km. and a maximum width of about 250 km. The basin is like a double fan.

The upper half of the basin in Madhya Pradesh State comprises undulating country with ridges and valleys whereas the lower half is fairly plain country. In Rajasthan, the basin consists of hills, forests and eroded terrain. In Gujarat, up to the confluence of the Mahi and the Panam rivers, the basin comprises semi-developed lands. Beyond Wanakbori, right up the Gulf of Cambay, is a flat, fertile and well developed alluvial tract.

THE RIVER SYSTEM

15.3 The Mahi is one of the major west-flowing rivers runing into the Gulf of Cambay and the third in order of size, the first two being the Narmada and the Tapi.

It rises on the northern slopes of the Vindhyas at north latitude 22°35′ and east longitude 74°58′ near the village of Sardarpur in the Dhar district of Madhya Pradesh State, at an elevation of about 500 metres. It first flows northwards for a length of 70 km. through the Dhar and Jhabua districts of Madhya Pradesh and is met in this reach by the Bagori from the left. Turning westwards, the river flows through Ratlam district for a length of 39 km. when it is met from the south by the Pampavati. Turning north-west thereafter, the river flows for another 58 km. to enter Rajasthan at Ambapara. In Rajasthan the Mahi flows in a south-westerly direction for 174 km. and is swelled by two important tributaries, the Som from the right, at the 279th km. of its run and the Anas from the left, at the 333rd km. of its run. Entering Gujarat at the 341st km. of its run, the Mahi continues to flow in a south-westerly direction. The Panam, an important tributary meets it from the left at the 402nd km. of its run. 26 km. further downstream, the river crosses the Wanakbori weir constructed in the Balasimor taluk of Kaira district and flows into the Gulf of Cambay after a run of 583 kms., of which 167 km. are in Madhya Pradesh, 174 km. in Rajasthan and the remaining 242 km. in Gujarat.

15.4 The principal tributaries of the river are the Som from the right and the Anas and the Panam from the left. These are described briefly in the following paragraphs.

The Som rises near Som on the eastern slopes of the Aravallies in the Udaipur district of Rajasthan at an elevation of about 600 m. and flows in a generally easterly direction for a total length of about 155 km. to join the Mahi from the right, opposite Sabla in the Dungarpur district of Rajasthan. The important tributaries of the Som are the Gomati and the Jakham from the left. The Som and its tributaries drain a total area of 8,707 sq. km.

The Anas rises near Kalmora on the northern slopes of the Vindhyas in Jhabua district at an elevation of 450 m. and flows in a generally north-westerly direction for a total length of about 156 km. to its confluence with the Mahi which joins it from the left, opposite Chikli village in the Dungarpur district of Rajasthan. The Anas drains an area of 5,604 km.

The Panam rises near Bhabra, on the northern slopes of the Vindhyas in Jhabua district at an elevation of 300 m. and flows in a generally north-westerly direction for a total length of about 127 km. to join the

Mahi, from the left opposite Wardhari in Panchmahals district of Gujarat. The Panam drains a total area of 2,470 sq. km.

CLIMATE

15.5 During the year, four distinct seasons occur in the basin. They are (*i*) winter, (*ii*) summer, (*iii*) monsoon and (*iv*) post-monsoon.

The winter season begins in December and continues to the end of February. January is the coldest month of the year. Clear bright weather, interspersed with brief spells of cloudy weather and accompanied by a little rain caused by the western disturbances traversing north India is experienced during this part of the year. Winds blow mainly from the north-east.

From March onwards, the hot weather starts and continues to the middle of June. Thunder storms occur occasionally during this season.

The south-west monsoon sets in by the middle of June and continues to be active till September. 95 per cent of the rainfall occurs during this period. Heavy showers generally occur in association with monsoon depressions from the Bay of Bengal and the Arabian Sea.

The south-west monsoon withdraws by the end of September and the weather clears up. Pleasant weather prevails till the end of December. Winds blow mainly from the north.

Rainfall

15.6 There are at present 52 reporting rain-gauge stations in the basin. The density of rain-gauges works out to one for 617 sq. km. The rain-gauges are insufficient in number and unevenly distributed. A few more rain-gauges should be established so as to cover the whole basin.

The rainfall data from all the existing rain-gauge stations are recorded and printed by the Rainfall Registration Authorities of the States concerned. This data appears in the annual volumes of the Daily Rainfall of India compiled and issued by the India Meteorological Department. Such volumes are available for the years from 1891 onwards. It will be seen that the major part of the basin receives a rainfall of 762 mm. The northern part of the basin comprising the drainage areas of the Som, Gomati and Jakham rivers gets only about 700 mm. of rainfall. During the monsoon months of June to September, the basin receives over 95% of the annual precipitation. The district-wise monthly and annual normals of rainfall based on records from 1901 to 1950, have also been published by the India Meteorological Department. According to this publication, the average monthly rainfall in the districts in the basin is given in Appendix 15.1.

Temperature

15.7 In January, during the winter season the minimum temperature over the catchment varies from 17.5°C to 20°C. The higher elevations in the upper and middle parts of the basin experience lower temperatures.

May is generally the hottest month of the summer. The mean maximum temperature is above 30°C. Temperatures are higher in the plains (lower reaches) than in the hills (upper reaches).

In the month of July of the rainy season, the mean temperature varies from 27.5°C to 30°C over the basin.

In the month of October of the post-monsoon season, the mean temperature over the basin varies from 27.5°C to 25°C.

Evaporation

15.8 Practically no data on evaporation is available for the Mahi Basin. The India Meteorological Department has compiled evaporation data for more than five years in respect of 30 departmental observatories and 42 agro-meteorological observatories scattered all over the country. Observations at all these places are taken with the standard U.S. Evaporation Pan (Class A) covered with wire-mesh. For the departmental observatories, the data pertains to the period 1959 to 1968 and is available month-wise, whereas the data for agro-meteorological observatories pertains to the period 1961 to 1968 and has been presented for the 12 periods into which the calendar year is divided for agro-meteorological purposes. No departmental observatory is located in the Mahi Basin. The only agro-meteorological observatory in the basin is at Vased.* The monthly evaporation from the reservoir as assumed in the Kadana project in the Mahi basin is shown in Table 15.2.

From the figures in this table it would appear that the assumed evaporation rates are lower than those indicated by the general meteorological condition at the sites.

SOILS

15.9 No systematic soil survey of the Mahi Basin has been carried out so far. The general data regarding soils of India, however, indicate that the basin consists mainly of red and black soils.

The basin partly covers the districts of Ratlam, Dhar and Jhabua in Madhya Pradesh, the whole of Banswara and a part of Udaipur, Dungar-

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*Evaporation Data (India), India Meteorological Department (April, 1970).

Table 15.2

Assumed Evaporation Rates in Kadana Project

Sl. No.	Name of the Project	Evaporation (cm.)												
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.	Kadana**	15	15	22	23	23	23	8	8	8	8	18	15	183

**Report on the Mahi Project Stage II (Kadana), Government of Gujarat (1959).

pur and Chittorgarh in Rajasthan, and part of the Panchmahals, Broach, Baroda, Sabarkantha and Kaira districts in Gujarat. The principal soil types found in the various districts in the basin are described below:*

Ratlam, Dhar and Jhabua

Medium black soil, which is not very deep and which is suitable for most crops.

Banaswara, Udaipur, Dungarpur and Chittorgarh

The eastern part of these districts has mixed red and black soils, whereas the western part has red and yellow soils.

Panchmahals

The soils are somewhat different from those in the other districts, in that they are residual soils, formed by the decomposition of granites and gneisses. They are light in colour, shallow and infertile, except for those situated in the lower plains which are darker, clayey and fertile. The fertile tracts are found along the banks of the Mahi.

Broach

Black and light soils with several sub-divisions.

Baroda

Black and 'goradu' soils (rich loams) the former in the southern and south-eastern portion and the latter in the northern portion.

Kaira

Four types namely light reddish brown or 'gorad', medium or 'besar', black or 'Kali' and alluvial or 'Bhata'.

Sabarkantha

Medium black soils occur in the major part of the district, while 'goradu' soils (rich loams) are found in the western portion.

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*Soils of India by S. P. Raychaudhari, R. R. Aggarwal, N. R. Datta Biswas, S. P. Gupta and P. K. Thomas.

LAND USE AND AGRICULTURAL PRACTICES

15.10 State-wise land use details in the basin, as in 1967–68 the latest year for which the statistics are available are given below:

Table 15.3

Land Use Details in the Mahi Basin

(Thousand hectares)

Sl. No.	Item	Name of State			Total
		Madhya Pradesh	Rajasthan	Gujarat	
1	2	3	4	5	6
1.	Gross area	670	1,645	1,169	3,484
2.	Reporting area	670	1,583	1,159	3,412
3.	Area under forest	80	163	238	481
4.	Area not available for cultivation	126	480	115	721
5.	Culturable area	464	940	806	2,210
6.	Uncultivated culturable area	174	454	56	684
7.	Net area sown	362	486	750	1,598
8.	Area sown more than once	21	94	86	201
9.	Total cropped area	383	580	836	1,799
10.	Net area irrigated	11.3	63.8	60.3	135.4
11.	Gross area irrigated	11.8	74.2	62.4	148.4
12.	Percentage of net area sown to culturable area	78.0	51.7	93.0	72.3
13.	Percentage of net area irrigated to culturable area	2.4	6.8	7.5	6.1
14.	Percentage of net area irrigated to net area sown	3.1	13.1	8.0	8.5

The culturable area in the basin is about 1.1% of the total culturable area of the country. The total cropped area in the basin is about 1.1% of the cropped area in the country.

The area under irrigated crops is about 8.2% of the cropped area in the basin.

15.11 The general cropping pattern, State-wise is described below:

Madhya Pradesh

Of the gross irrigated area of nearly 11,800 hectares, 33.1% is under wheat, 5.1% under sugarcane and 18.6% under gram and 9.3% under cotton. Other irrigated crops are maize, barley, jowar, bajra, millets, ground-nut, sesamum, rape, mustard, fruits, vegetables, linseed, tobacco and fodder crops.

Food and non-food crops cover about 83.9% and 16.1% of the irrigated cropped area respectively.

Rajasthan

Of the gross irrigated area of about 74,200 hectares, 24.7% is under wheat, 18.3% under barley, 6.5% under cotton and 5.6% under gram. Other irrigated crops are maize, paddy, sugarcane, jowar, bajra, millets, condiments, spices, fruits, vegetables, groundnut, sesamum, rape, mustard, linseed, tobacco and fodder crops.

Food and non-food crops cover about 86.9% and 13.1% of the irrigated cropped area respectively.

Gujarat

Of the total irrigated area of about 63,400 hectares, 27.9% is under wheat, 21.8% under paddy, 9.6% under cotton and 1.4% under maize. The other irrigated crops are barley, gram, sugarcane, jowar, bajra, millets, condiments, spices, fruits, vegetables, tobacco and fodder crops.

Food and non-food crops cover about 78.5% and 21.5% of the irrigated cropped area respectively.

summing up, of the total irrigated area in the basin, 26.5% is under wheat, 9.2% under barley, 8.0% under cotton, 10.6% under paddy, 1.6% under sugarcane and 4.4% under gram and the rest under miscellaneous crops. 83.2% of the total irrigated area is under food crops and the balance 16.8% under non-food crops.

15.12 In Madhya Pradesh, there are two main crop seasons namely (i) Kharif and (ii) rabi. The Kharif crops are sown from June to August and harvested from September to December depending on the crop grown. The important crops grown in this season are jowar, bajra, maize, pulses, groundnut, and oilseeds. The rabi crops are sown from October to December and harvested from February to May. The important rabi crops are wheat, barley and gram. Sugarcane is sown from January to May and harvested from November to February.

15.13 In Rajasthan, there are two main crop seasons, namely (i) kharif and (ii) rabi. The kharif crops are sown from June to August and harvested from September to December, depending on the crop grown. Important crops grown in this season are paddy, jowar, bajra, maize and millets. The rabi crops are sown from October to December and harvested from February to May. Important rabi crops grown are wheat, barley and gram. Sugarcane is sown from January to May and harvested from November to February. There is a wide variation in the cropping patterns followed in the various districts in the basin. In Udaipur district a major portion of the cropped area is under the primary cereals viz. wheat, barley, rice and maize. Other crops grown are millets, gram, pulses, oilseeds and cotton. In the Dungarpur area also, primary cereals occupy large areas.

15.14 In Gujarat as in Rajasthan, there are two crop seasons, namely (i) Kharif and (ii) rabi. The kharif crops are sown in the period June to August and harvested from October to December. The rabi crops are sown in October to November and harvested in February to March. The crop pattern varies considerably within the region. In Panchmahals, which is a hilly district, more than three fourths of the cultivated area is devoted to food-grains. Rice and maize are the important crops followed by tur and gram. Kaira district has a well-diversified cropping pattern, the important crops being rice, wheat, cotton and tobacco. Among the cereals, bajra is the most important crop. Cotton is the most important crop in Baroda district occupying 45% of the cropped area, followed by rice and jowar.

REGIONAL ECONOMY

Population

15.15 On the basis of the 1971 census* and the percentages of the area of each district within the basin to the district as a whole, the total population in the basin is about 5.03 millions. The State-wise distribution is shown below:

Table 15.4

Population in the Mahi Basin

State	Population (million)
Madhya Pradesh	0.74
Rajasthan	1.92
Gujarat	2.37
Total	5.03

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*Census Paper I of 1971 (Supplementary), Registrar-General (India).

There is no city in the basin which has a population of more than one lakh. While densities vary from region to region, the average density of population in the basin is 144 persons per sq. km. The most densely populated district of Kaira has 340 persons per sq. km. while the district of Chittorgarh with 87 persons per sq. km. is at the other extreme. 86.1% of the population live in rural areas and the remaining 13.9% live in cities and towns. The working force constitutes about 34.3% of the population. Nearly 52.7% of the working force is engaged in cultivation, 20.8% as agricultural labourers and the remaining 26.5% is employed on other activities.

Forests & Agriculture

15.16 Forests and agriculture are the mainstay of the people. Nearly 14.1% of the total area of the basin is covered with forests, which are largely confined to Jhabua, Banswada, Udaipur and Dungarpur districts and are mainly of the dry tropical variety. The area annually cropped in the basin is about 1.80 million hectares. Agriculture is generally rain-fed with relatively low yields except for about 0.15 million hectares of irrigated area, which grows mainly wheat and cotton.

Power

15.17 The Central Water & Power Commission which conducted surveys to assess the hydroelectric potential of the country has worked out the hydroelectric potential of the Mahi Basin as 33 MW at a 60% load factor. At present, the demand for the electrification of towns and industries etc. is mainly met from diesel and thermal power plants. There are no major hydro or thermal stations within the basin at present.

Mineral Wealth

15.18 The principal minerals found in the basin are*

Bauxite: In the Jhabua district of Madhya Pradesh and the Kaira district of Gujarat. The quality of the ore is good although the deposit is of minor importance.

Manganese: In the Jhabua district of Madhya Pradesh, the Baroda district of Gujarat and the Banaswada and Udipur districts of Rajasthan.

Fire Clay and China Clay: In the Jhabua district of Madhya Pradesh and near Darol in the Panchmahals district of Gujarat. China clay is also found in Udaipur district. A variety of clays is found in Broach district of Gujarat.

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*Techno-Economic Surveys of Gujarat, Madhya Pradesh and Rajasthan, NCAER.

Talc and Soap-stone: In the Jhabua district and Talc in the Udaipur district.

Asbestos: Near Jobat in Jhabua district and in Udaipur district. The asbestos found in Jhabua district is brittle and sharp-fibred and can be used in the manufacture of shingles, asbestos insulin, asbestos pains and various asbestos-mounted articles.

Limestone: Extensive lime deposits have been found in the Kaira and Broach districts of Gujarat and in the Chittorgarh district of Rajasthan. These need further investigation.

Glass Sand deposits: In Baroda district.

Lead and Zinc: In the hills of Udaipur district.

Iron Ore deposits: On a small scale and in a scattered fashion, in Udaipur district.

Mica: In Udaipur district.

Fluoride: Which has important metallurgical uses in steel, ferro-alloys and aluminium industries, in Dungarpur district.

Emerald: In Udaipur district.

Graphite: Deposits in Banaswara district but of low grade.

Industries

15.19 The important industries in the basin are described below:

Ratlam: Cotton textiles, paper, cardboard and newsprint, drugs and pharmaceuticals.

Communications

15.20 The basin is served by the network of the Western Railway. Some of the important routes are, the Bombay-Baroda-Ratlam-Delhi line, the Godhra-Boker-Anand line and the Bhadram-Petled-Nadiad line.

The important National Highway connecting Bombay-Baroda-Ahmedabad passes through the lower part of the basin. There are also several state Highways and district roads, connecting important towns. The part of the basin lying in Gujarat has good road communications whereas the part of the basin falling in Rajasthan and Madhya Pradesh has comparatively poorer road communications.

The river and its tributaries are not navigable.

In general, the lower part of the basin is better served with communications in comparison with the middle and upper parts which lack communication facilities.

15.21 The economy of the basin at present largely depends on agriculture, which, in view of the low rainfall and its uneven incidence, produces a low level of subsistence, except for limited areas where facilities for irrigation have been provided and where agro-based industries have developed. There is a keen demand in the basin for the development of the available water resources.

WATER RESOURCES

Surface Waters

15.22 In the absence of observed records of flow the First Irrigation Commission had assessed the surface flow in all the west-flowing rivers except the Narmada and Tapi as 230,784 m. cu. m.* based on a co-efficient selected with regard to the rainfall and other conditions and to the co-efficient of actual flow determined for other catchments.

In 1949, a basin-wise assessment of the water resources of the country was made on the basis of Khosla's empirical formula. The annual runoff of the Mahi Basin had been assessed as 9,313 m. cu. m.**

In 1960, the Central Water & Power Commission, while conducting irrigation potential studies, assessed the average annual runoff of the Mahi river system based on observed records of flow as 11,812 m. cu. m.†

There has been no planned or systematic observation of discharges on the Mahi and its tributaries. Some ad hoc and irregular observations have been made on the main river in Rajasthan and Gujarat States, whereas in Madhya Pradesh no observations seem to have been made so far. The details of the existing gauge and discharge sites are given in Table 15.5. The data available for most of the sites is incomplete. Many sites seem to have been established recently and for a short period.

As the observations at existing sites have been neither continuous nor systematic, they need to be standardised and made continuous. In the upper reaches of the river in Madhya Pradesh State, there is no discharge site at present. One new gauge and discharge site near Raoti village in Ratlam district across the main Mahi may also be established to cover the deficiencies in the existing hydrological network.

Under the programme of maintaining centrally sponsored key hydrological stations in the country, the Central Water and Power Commission has proposed the inclusion of the gauge and discharge sites on the Mahi at Panchabear in Rajasthan State and the Kadana Dam site in Gujarat. In addition, they have suggested that the gauge and discharge sites on the

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*Report of the Indian Irrigation Commission (1901-03).

**An appraisal of water resources by Dr. A. N. Khosla UNESCO.

†Report of technological possibilities of irrigation projects in India, Central Water and Power Commission (Unpublished).

Table 15.5

Existing Gauge and Discharge Sites

Sl. No.	Name of Station	Name of river	Observations made for	Remarks
1	2	3	4	5
Rajasthan				
1.	Mahi (Madhya Pradesh border)	Mahi	Gauge	
2.	Mahi (Banaswara Dam site)	Mahi	-do-	
3.	Mahi (Gujarat border)	Mahi	-do-	
4.	Anas	Anas	-do-	
5.	Jakham	Jakham	-do-	
6.	Karhi	Karhi	-do-	
7.	Som	Som	-do-	
Gujarat				
8.	Limdi	Machhan	Gauge & Discharge	
9.	Kadana	Mahi	-do-	
10.	Mataria Vejma	Madaf	-do-	
11.	Sagawada	Panam	-do-	
12.	Lunawada	Panam	-do-	
13.	Itadi	Mahi	-do-	
14.	Vasad	Mahi	-do-	
15.	Wanakbori weir	Mahi	-do-	

Source: Replies of Rajasthan and Gujarat to the Questionnaire issued by the Irrigation Commission.

Mahi near Sagawada in Rajasthan and Mahi-Itadi in Gujarat may be maintained by the States concerned.

The Gujarat State Government have made studies using the short-term runoff data available from 1954 at the Kadana site to arrive at a rainfall runoff correlation and have worked out on that basis, a 75 years runoff series. The annual runoffs of the Mahi at the Kadana site at different percentages of dependabilities as determined from the above runoff series are shown below:

Site	*Catchment area*	*Annual runoff at % dependability* (M. cu. m.)		
		50%	75%	90%
Kadana	25,501 sq. km.	7,702	4,361	2,124

Ground Waters

15.23 Systematic investigations and studies of the ground water potential of the Mahi basin have not been made so far. Only in some parts of Broach, Baroda and Panchmahals districts have some investigations and studies been made recently. Investigations in the Mahi-

Narmada inter-stream area, west of longitude 73°45′, have indicated* that the area is underlain by rocks belonging to the banded gneissic complex comprising granites and gneisses; the Champaner series comprising quartzites and phyllites; the Songhir series comprising sandstones and limestones; Deccan traps comprising basalt flows; alluvium consisting of clay, sand and boulder gravel and acolion sands. Banded gneisses, Champaner series and Deccan traps are poor water yielders. It is not known if the limestones of the Songhir series are cavernous and the sandstones permeable. The depth of the water-table in the area ranges from 0 to 35 metres gradually decreasing towards the west. The water-table outcrops along the Mahi river, which receives part of the ground water discharge which flows down to the sea. The boulder gravel, which occurs below the water-table throughout the alluvial area, is a potential aquifer inter-connected with river beds. The quality of ground water deteriorates as the depth of the aquifer increases. There is a gradual increase in the salinity of ground water towards the coast. The fresh water zone gradually tapers off towards the west.

Investigations carried out in Lunawada and other parts of Godhra taluk have indicated that ground water occurs in the Aravallies and post-Delhi granites. Patches of alluvium occur across the Mahi and Panam rivers, the most significant and promising patch being on the north side of the Mahi river between Charangam and Harod.

Investigations carried out so far, point to the urgency and importance of further systematic exploratory work in the basin for a scientific, quantitative and qualitative assessment of the ground water resources. Such an assessment, which will help in framing a rational plan of development for various needs, can only be made when full investigations are carried out.

EXISTING DEVELOPMENT

15.24 The First Irrigation Commission had not recommended any specific projects by name, to be taken up for construction in the Mahi basin.**

The Jaisamand Tank project (Dhebar Lake) in the Udaipur district of Rajasthan is the oldest irrigation system in the basin. The tank is constructed across the Gomati, a tributary of the Som, which, in turn, is a tributary of the Mahi.† A 57.9 km. long canal system irrigates a total area of 4,050 hectares. The project cost Rs. 6 million.

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*Ground Water Resources of India, status and surveys, prospects and perspectives, Geological Survey of India (August, 1970).

**Report of the Indian Irrigation Commission (1901-03).

†Report of the technological possibilities of irrigation projects in India CW&PC (unpublished).

A number of medium projects have been taken up for construction in the Mahi basin during the Plan periods. The salient features of the projects completed in the pre-Plan and Plan periods are shown in Appendix 15.2.

Appendix 15.3 shows the major and medium projects under construction in the Mahi basin in the different States. These projects are described in the following paragraphs:

Pampavati Project

The project, situated in the Jhabua district of Madhya Pradesh, provides for the construction of an earthen dam across the Pampawati, a tributary of the Mahi with a canal system to irrigate about 1,093 hectares. It was taken up for construction in 1967 and is expected to be completed during the Fourth Plan. The estimated cost of the project is Rs. 5.85 million.

Mahi Right Bank Canal (Mahi—Stage I)

The project consists of a pick-up weir across the river Mahi, near Wanakbori village, in the Balasinor taluka, district Kaira, in Gujarat State, with a 304 km. long canal system on the right bank. The 796 m. long stone masonry weir has a maximum height of 20.6 m. The canal system irrigates an area of 186,162 hectares. The project costing Rs. 245.68 million was started in 1948 and is expected to be completed by the end of Fourth Plan.

Kadana Project (Mahi—Stage II)

This project envisages a masonry-cum-earth dam across the river Mahi at Kadana, about 70.8 km. up-stream of the Wanakbori weir, in the Santrampur taluka, district Panchmahals, of Gujarat State. The 2,225 m. long dam will have a maximum height of 58.2 m. above the deepest foundation. The reservoir created by the dam will have a gross storage of 1,700 m. cu. m., out of which, 1,300 m. cu. m. will be the live storage. The main canal taking off on the left bank will run for a length of 106 km. and irrigate an area of 16,554 hectares. In addition, the irrigation under the Mahi right bank canal, taking off from the Wanakbori weir, will be firmed up and extended by 270,000 hectares. The total cost of the project is estimated at Rs. 210.01 million. Work on the project, which began in 1956, is expected to be completed by the end of Fourth Plan.

Besides the major and medium projects in the Mahi basin, minor schemes comprising tanks and wells irrigate a large area. The details of the area irrigated by various sources like canals, tanks, wells etc., during the year 1967–68, State-wise, in the basin are shown in Table 15.6.

Table 15.6

Source-wise Irrigation

(Thousand hectares)

Sl. No.	Source of irrigation	State			Total
		Madhya Pradesh	Rajasthan	Gujarat	
1	2	3	4	5	6
1.	Canals	0.3	—	18.7	19.0
2.	Tanks	0.3	14.6	4.3	19.2
3.	Open wells	10.2	48.3	36.7	95.2
4.	Other sources	0.5	0.9	0.6	2.0
	Total	11.3	63.8	60.3	135.4

By the end of 1968-69 the area under minor schemes increased by about 7,750 hectares.

The major and medium projects in operation and under construction in 1968-69 in the basin, on completion and full development, will use 2,832 m. cu. m. of water. The reservoir losses have been estimated approximately by the Commission in the absence of any data, at the rate of 20% of the total annual diversions. The reservoir losses work out to 566 m. cu. m. The total utilisation by major and medium projects including reservoir losses would thus be of the order of 3,398 m. cu. m.

In the absence of any statistics for minor schemes, the utilisation by such projects has been estimated by the Commission on the basis of the total area irrigated from these sources. On completion and full development the minor projects under operation and construction in 1968-69 would use about 1,515 m. cu. m. (including tank losses).

The total utilisation by major, medium and minor projects undertaken up to the beginning of the Fourth Plan, on their completion and full development, is of the order of 4,913 m. cu. m. of which 3,830 m. cu. m. is from surface waters and 1,083 m. cu. m. from ground waters.

The data on industrial needs in the basin are not readily available. So far, the problem of water pollution by industrial wastes has not been reported.

FUTURE DEVELOPMENT

15.25 Two major projects and one medium project are proposed to be taken up for construction in the basin in the Fourth Five Year Plan period. Of these, one major and one medium project are in Rajasthan.

The other major project is in Gujarat. Appendix 15.4 shows the salient features of these projects. The projects are described briefly in the following paragraphs:

Mahi (Banaswara) Project

The project comprises a 301 m. long masonry-cum-earth dam across the Mahi near Borkhera village, about 60 km. north-east of Banaswara town in Rajasthan State. The reservoir will have a gross storage capacity of 2,043 m. cu. m. of which the live storage will be 1,701 m. cu. m. Two canals take off, one on each bank, to irrigate 30,750 hectares. The project will also generate power. The cost of the irrigation part of the project is Rs. 42.5 million.

Jakham (Part II) Project

The project provides for a masonry dam 62 m. high across the Jakham river near village Heldukhera in the Udaipur district of Rajasthan State. The reservoir created by the dam will have a live storage of 112 m. cu. m. The storage will be utilised to extend irrigation under the existing Jakham weir and canal system which forms Part I of the project. A total area of 11,520 hectares will get irrigation benefits. The project is expected to cost Rs. 30.0 million.

Panam Reservoir Project

This project comprises a storage dam across the Panam river, a tributary of the Mahi in the Panchmahals district of Gujarat State. The dam will be 269 m. long and 55.4 m. high. The main canal will be 78.84 km. long and will irrigate 21,870 hectares. The estimated cost of the project is Rs. 101.12 million.

On completion and full development, the above projects will utilise about 2,637 m. cu. m. of Mahi waters including reservoir losses.

By the end of the Fourth Plan, the area under minor schemes is expected to increase by about 53,610 hectares requiring nearly 654 m. cu. m. of water, including reservoir losses.

Thus, the additional utilisation by the Fourth Plan major, medium and minor projects would be of the order of 3,291 m. cu. m. benefiting an area of 117,750 hectares. On completion and development of the Fourth Plan projects, about 8,204 m. cu. m. of waters (6,654 m. cu. m. of surface waters and 1,550 m. cu. m. of ground waters) would have been used for irrigating a total area of 531,226 hectares.

The Madhya Pradesh State Government has not indicated any new projects in the basin. Rajasthan contemplates taking up two major projects and two medium projects in the future. The details of these are given below:

Table 15.7

New Projects Proposed in Rajasthan

Sl. No.	Name of the Project	Zone/ District	Source of supply (Name of river)	Ultimate irrigation ('000 hec.)
1	2	3	4	5
1.	Anas Multipurpose Project	Banaswara	Anas	121.41
2.	Baneshwar Multipurpose Project	Banswara	Mahi	202.34
3.	Daia	Udaipur	Daia	1.24
4.	Somkamla Amba	Dungarpur	Som	7.20

The Gujarat State has in view the Kadana Righat Bank High Level Canal Project, which is dependent on the Navgam High Level Canal Project on the Narmada. When the Navgam High Level Canal materialises, a part of the area which is being irrigated by Mahi waters in the basin will be fed by the Narmada waters and to that extent Mahi waters will be released for utilisation by the Kadana High Level Canal.

Appendix 15.5 shows the details of the new schemes proposed by the various State Governments in the Mahi basin.

FLOODS, WATERLOGGING AND DRAINAGE

15.26 The Mahi basin is influenced by the south-west monsoon. The flows in the river are considerable during the monsoon period and dwindle rapidly in the post-monsoon period. The flows are negligible in the hot weather. High floods are experienced in the monsoon months of July and August. The highest flood discharge, as observed at Pali, 18 km. downstream of the Wanakbori weir site in June, 1919 was of the order of 25,004 cumecs. The highest flood discharge observed at the railway bridge near Vasad, 56 km. downstream of the Wanakbori weir is 29,705 cumecs. Because the catchment area of the basin is in the shape of a double fan, it is particularly suited to produce a high flood discharge. As the river flows in a defined channel with high banks, damage due to floods has not occurred on a large scale. The river does not seem to have over-topped its banks during record floods in the past, unlike other major rivers like the Narmada and the Tapi. Small patches of land at the tail end of the Mahi Project—Stage I Command in the Mater and Cambay talukas are affected by floods in the Watrak at its confluence with the Sabarmati. The records of the damage caused by floods in this river are not available. No major flood control works have been undertaken in the basin.

15.27 Waterlogging due to existing flow irrigation projects in the basin like the Mahi Project—Stage I etc., has been negligible as there is very little perennial irrigation and is also not expected to cause concern in the future, as proper drainage facilities have been planned in areas which are likely to get waterlogged.

SOIL CONSERVATION

15.28 Soil erosion in the Mahi basin is mainly due to wind erosion and the formation of ravines. Wind erosion occurs in the part of the basin lying in Rajasthan State. On the rocky hills and plateaus where the soil is shallow and devoid of vegetation, the top soil is blown away by high velocity winds. Improper land use causes accelerated soil erosion and leads to the formation of gulleys and ultimately ravines. It is estimated that nearly four lakh hectares in Gujarat State covering the Sabarmati, Mahi, Banas and Narmada basins is affected by ravines. The control and reclamation of ravines can be achieved by the construction of marginal bunds for diversion channels in the catchment feeding the ravines; by the construction of check dams or gully plugs in the ravines at proper intervals; by toning down or easing the steep slopes of the gully banks to the angle of natural repose and sodding the slopes with vines and grasses with soil-binding tendencies; by planting suitable fast-growing trees and shrubs along the bank of rivers and in the cut-up areas which are unfit for other purposes; by constructing wire-crate walls and by introducing better farming practices and soil conservation measures in the table-lands of the catchment.

The basin has hardly 14.1% of area under forests. This percentage is low compared to the all-India average and the standard laid down in the 1952 Forest Policy Resolution of the Government. Afforestation of the catchment is called for to reduce erosion hazards.

No data is available regarding the silting of existing tanks and reservoirs in the basin. For the conservation of river supplies and especially of the storage capacities created in the reservoirs, it is important for soil conservation measures to be taken up in the basin. Soil conservation measures may be classified under the following heads:

(i) Afforestation in new areas as well as in existing forests which have been either denuded or where replacement is needed;

(ii) terracing and contour bunding and the construction of field bunds on agricultural lands which require treatment;

(iii) pasture development and the protection of marginal and sub-marginal lands; and

(iv) stream control measures including fringe afforestation and stream bank control.

No scheme in the Mahi basin has been included under the Centrally sponsored programme of soil conservation in the catchments of major river valley projects.

GENERAL

15.29 The Mahi and its tributaries are an inter-State river system flowing through the States of Madhya Pradesh, Rajasthan and Gujarat. A number of projects have already been constructed in the basin. One medium project in Madhya Pradesh and two major projects in Gujarat State are under construction.

15.30 In regard to the distribution and utilisation of Mahi water, an agreement exists between the concerned States. An agreement was reached in 1961 between the Madhya Pradesh and Rajasthan Governments whereby it was decided that 368 m. cu. m. of water be earmarked to Madhya Pradesh for upstream utilisation. As the points of utilisation were near the periphery of the Banaswara reservoir, it was expected that 85 m. cu. m. could be taken as regeneration water in the Mahi reservoir and hence it was agreed that a net quantity of 283 m. cu. m. should be reserved for upstream utilisation in Madhya Pradesh. Subsequently, in January, 1966, an agreement was reached between the Rajasthan and Gujarat Governments whereby the Gujarat Government was allowed to construct the Kadana reservoir up to FRL 410 and enjoy all the benefits therefrom. It was also decided that the Gujarat Government would share the cost of construction of the Banaswara Project in proportion to the benefits of regulated releases which Gujarat would receive from the project.

15.31 The number and distribution of rain-gauge stations should be reviewed and new stations to fill the gaps shoud be established. It is also important that the daily rainfall data for all these stations should be published on a monthly basis, preferably sub-basinwise.

15.32 A network of evaporation-measurement stations particularly at the sites of existing and proposed reservoirs needs to be established.

15.33 Gauge and discharge observations of the various sites in the basin should be continued on a permanent basis to obtain data essential not only for the preparation of individual projects but also for the regulation, to the best advantage, of the available river water in any year.

15.34 Systematic and scientific exploratory work is needed for a quantitative and qualitative assessment of the ground water resources in the basin, so that these resources can be exploited in a rational way either independently or in conjunction with surface waters.

15.35 There is need for inter-State co-operation and agreement in respect of carrying out soil conservation measures and conserving the storage capacities of existing and proposed reservoirs in the basin.

15.36 It is necessary for systematic data to be collected with regard to the sediment carried by the rivers which would be of considerable use in working out the dead storage and the lives of reservoirs. It will also reflect the effect of soil conservation works carried out in the basin.

THE DHADHAR BASIN

15.37 The Dhadhar basin is located in between the Mahi and the Narmada basins in Gujarat State. It extends over an area of 2,770 sq. km. and lies between east longitudes 72°30′ and 73°40′ and north latitudes 21°50′ and 22°35′.

15.38 The Dhadhar river rises near Ghanta village, at north latitude 22°30′ and east longitude 73°35′, in the Panchmahals district of Gujarat State, at an elevation of 150 metres above mean sea level and flows generally in a south-westerly direction for a total length of 135 km., to outfall into the Gulf of Cambay.

15.39 The basin experiences four seasons in the year namely (i) winter, (ii) summer, (iii) monsoon and (iv) post-monsoon.

15.40 There are 21 reporting rain-gauge stations inside the basin. The distribution of the stations is fairly even and the number sufficient. The annual rainfall varies from 760 mm. to 890 mm. 95 per cent of the rainfall occurs during the monsoon months from June to September.

15.41 The temperature variations in the basin during the different seasons are as follows.

Season	*Mean temperature*
Winter	20°C
Summer	above 30°C
Monsoon	27.5° to 30°C
Post-monsoon	27.5°C

15.42 Evaporation data for the basin is not available.

15.43 Systematic soil survey of the basin has not been done. The general data on soils of the country indicates that the basin consists of mainly medium and deep black soils, and coastal alluvium. The basin partly covers the districts of Panchmahals, Baroda and Broach in Gujarat State. Medium black soils are found in Panchmahals district whereas deep black soils occur in Baroda and coastal alluvium in Broach district.*

15.44 The land use details in the basin as in 1967–68, the latest year for which the statistics are available are given in the following table.

Table 15.8

Land Use Details in the Dhadhar Basin

Sl. No.	Item	Area in thousand hectares
1	2	3
1.	Gross area	277
2.	Reporting area	276
3.	Area under forest	45
4.	Area not available for cultivation	30
5.	Culturable area	201
6.	Uncultivated culturable area	27
7.	Net area sown	174
8.	Area sown more than once	8
9.	Total cropped area	182
10.	Net area irrigated	14
11.	Gross area irrigated	15.3

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*Indian Crop Calendar, Directorate of Economics and Statistics, Ministry of Food, Agriculture, C.D. and Cooperation (1967).

Table 15.8—Contd.

1	2	3
12.	Percentage of net area sown to culturable area	86.6
13.	Percentage of net area irrigated to culturable area	7.0
14.	Percentage of net area irrigated to net area sown	8.0

The area under irrigated crops is about 8.4% of the cropped area in the basin.

15.45 The general cropping pattern is described below:
Of the gross irrigated area of about 15,300 hectares, nearly 45.1% is under cotton, 13.7% under wheat, 11.1% under paddy 6.5% under tobacco and the rest under other crops like jowar, condiments and spices, fodder crops, bajra, maize, barley, gram, sugarcane, fruits and vegetables and other non-food crops. Food and non-food crops cover about 41.8% and 58.2% of the irrigated cropped area respectively.

15.46 There are two crop seasons, namely (i) kharif and (ii) rabi. Kharif crops are sown in the period June-August and harvested from October-December. The rabi crops are sown in October-November and harvested in February-March. The crop pattern varies from district to district. In Panchmahals, more than three-fourths of the cultivated area is devoted to foodgrains. Rice and maize are the important crops followed by tur and gram. Cotton is the most important crop in the Baroda and Broach districts.

15.47 On the basis of the 1971 Census* and the percentages of the area of each district within the basin to the district as a whole, the total population in the basin is about 0.58 million. Only one city, Baroda, has a population of more than one lakh. The average density of population in the basin is 210 persons per sq. km. The most densely populated district is Baroda with 254 persons per sq. km. and the least populated district is Broach with 122 persons per sq. km.

15.48 Forests cover 16.3% of the basin area. The area annually cropped in the basin is about 0.18 million hectares. Agriculture is generally rain-fed, with relatively low yields except for about 15,300 hectares of irrigated area, which mainly grows cotton and wheat.

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*Census Paper 1 of 1971 (Supplementary), Registrar-General (India).

15.49 Neither hydro nor thermal power stations are located in the basin at present.

Manganese is the only important mineral found in the upper reaches of the basin.*

15.50 There is a heavy concentration of industries in and around Baroda. The main industries are cotton textiles, rubber and rubber goods, plastic and allied products, alcohol, glass and ceramics, electrical equipment and appliances, agricultural equipment, machine tools, radio and electronics, machinery and machine parts, metal tubes and conduits, chemicals, inks, paints and varnishes, fertilizers, D.D.T. and insecticides and drugs and pharmaceuticals.

15.51 The basin is served by the Western Railway. The National Highway connecting Bombay and Ahmedabad passes through the basin, in addition to State Highway and several district roads. The river is not navigable. The basin has fairly well developed communications.

15.52 Gauges and discharges in the basin are being observed by the Gujarat State at the following sites: **

Site	*River*
(i) Vejalpur	Deo tributary
(ii) Bhamaria	-do
(iii) Bhilapur	Main Dhadhar

The observations seem to have been started recently. The observations have to be continued in a standard and systematic manner. There is no gauge and discharge site in the lower reaches of the river. It is suggested that the discharges may be observed on the main river near Jambusar. The total annual flow of the Dhadhar System had been assessed by the Central Water & Power Commission at the time of irrigation potential studies, in 1960, as 704 m. cu. m., based on Strange's rainfall-runoff coefficients.

15.53 The basin is underlain by granites, gneisses, phyllites, sandstones, limestones, Deccan Traps and alluvium.* Except alluvium, which has the possibility of deep ground water development, the other formations are poor ground water yielders. Systematic exploratory work has to be done to assess, quantitatively and qualitatively, the ground water resources.

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*Techno-Economic Survey of Gujarat, NCAER.

**Hydrological Data (Parts I & II), PWD, Government of Gujarat, 1965.

15.54 The first Indian Irrigation Commission had not recommended any specific project by name to be taken up for construction in this basin.** No major and medium projects were constructed either in the pre-Plan or in the Plan periods. All the projects, existing and under construction in the basin are minor schemes. Details of the area irrigated by various sources like canals, tanks, wells etc. during the year (1967–68) are shown below:

Source of Irrigation	*Area irrigated ('000 hectares)*
(i) Canals	1.00
(ii) Tanks	1.10
(iii) Tubewells	0.1
(iv) Open wells	11.3
(v) Other sources	0.5
Total	14.0

By the end of 1968–69 the area under minor schemes increased by about 1,070 hectares.

15.55 According to the data furnished by the Gujarat Government, there were no tanks in the basin prior to 1950. During the period 1950–69, the following seven minor tanks have been constructed:

Sl. No.	*Name of the Tank*	*Location/District*
1.	Ankhi-Hiran	Broach
2.	Raval	Baroda
3.	Haripura	Baroda

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*Ground Water Resources of India, Status and Surveys, Prospects and Perspectives, Geological Survey of India (August, 1970).

**Report of the Indian Irrigation Commission (1901-03).

Sl. No.	*Name of the Tank*	*Location/District*
4.	Shripore Timbi	Baroda
5.	Vada	Panchmahals
6.	Palanpur	-do-
7.	Zinzari	-do-

The following minor tanks are under construction:

Sl. No.	*Name of the Scheme*	*Location/District*
1.	Dhadhar near Magnad	Broach
2.	Kundanpur	Baroda
3.	Vesania	Baroda

15.56 Information in respect of the utilisation by the minor schemes is not available. On the basis of the total area irrigated by the minor schemes and rough duties, the Commission has estimated the approximate utilisation. On completion and full development, the schemes under operation and construction in 1968–69 are expected to use about 171 m. cu. m. of water, of which 41 m. cu. m. is from surface water and 130 m. cu. m. from ground water.

15.57 A large number of industries are located in and around Baroda. The extent of the industrial use of Dhadhar water is not known. With the concentration of industries around Baroda, water pollution by industrial waste in the lower reaches needs to be guarded against.

15.58 No major or medium project has been proposed by the Gujarat State to be taken up for construction in the basin in the Fourth Five Year Plan period. The area under minor schemes in the Fourth Plan period is expected to increase by 7,050 hectares requiring 80 m. cu. m. (inclusive of tank losses) of which 19 m. cu. m. will be from surface water and 61 m. cu. m. from ground water. Thus by the end of Fourth Plan, 251 m. cu. m. of water (60 m. cu. m. of surface water + 191 m. cu. m. of ground water) would have been utilised to irrigate 22,120 hectares, in the basin. New schemes to be taken up in the future have also not been indicated. However, when the Navgam High Level Canal materialises, a large part of the Dhadhar basin will get irrigation from the Narmada water.

15.59 There is no serious flood problem in the basin. No flood control measures have been undertaken.

15.60 No soil conservation measures appear to have been undertaken in the basin. There being no major scheme in the basin, no works on soil conservation, under the Centrally sponsored programme, have been undertaken. As the basin has hardly 16.3% of its area under forests, afforestation is called for to reduce the hazards of erosion. Other soil conservation measures on agricultural lands also need to be taken up to conserve the storage capacities of reservoirs in the basin.

GENERAL

15.61 Evaporation-measuring stations need to be established.

15.62 Gauge and Discharge observations at various sites should be conducted in a systematic manner and continued on a long-term basis.

SALIENT FEATURES OF THE SABARMATI BASIN

(i) Source	In the Aravalli hills in Rajasthan, near the popular shrine of Amba Bhavani. (Latitude 24°40′N, Longitude 73°20′E)		
(ii) Length of Sabarmati river	in Rajasthan	4 km.	30 miles
	in Gujarat	323 km.	200 miles
	Total	371 km.	230 miles
(iii) Drainage area	in Rajasthan	4,124 sq.km.	1,592 sq.miles
	in Gujarat	17,550 ,,	6,776 ,,
	Total	21,674 ,,	8,368 ,,
(iv) Population (1971 Census)		4.77 millions	
(v) Density of population		220 per sq.km.	570 per sq.mile
		Cumecs	Cusecs
(vi) Maximum discharge at Ahmedabad 245 km. (152 miles) from source on 19.9.1950		11,574.70	409,000.00
(vii) Minimum discharge at Ahmedabad on 24-4-1952		0.71	25.07
(viii) Average Annual runoff		m. cu. m.	MAF
(a) As per Khosla's formula		4,663	3.78
(b) As per irrigation potential studies of CW&PC.		3,663	2.97
(ix) Maximum annual runoff recorded to date (at Ahmedabad in 1956-57)		4,018.80	3.23
(x) Minimum annual runoff recorded to date (at Ahmedabad in 1957-58)		528.34	0.43
		Thousand hectares	Thousand acres
(xi) Culturable area (1967-68)		1,548	3,825
(xii) Net area sown (1967-68)		1,264	3,123
(xiii) Gross area sown (1967-68)		1,403	3,467
(xiv) Net area irrigated (1967-68)		216	534
(xv) Gross area irrigated (1967-68)		225	556
(xvi) Area irrigated after completion and full development of Fourth Plan projects		380	939
(xvii) Probable additional irrigation by future projects		Nil	Nil

		m. cu. m.	MAF
(xviii) Water utilisation, including reservoir losses			
(a) On completion and full development of major, medium and minor projects under operation and construction in 1968-69	Surface water	1,470.47	1.19
	Ground water	1,826.00	1.48
	Total	3,296.47	2.67
(b) On completion and full development of Fourth Plan projects:	Surface water	2,201.00	1.78
	Ground water	2,308.00	1.87
	Total	4,509.00	3.65

CHAPTER XVI

THE SABARMATI BASIN

The Sabarmati basin extends over an area of 21,674 sq. km., and lies between east longitudes 72°15′ and 73°49′ and north latitudes 22°15′ and 24°53′. Located in Western India, the basin covers areas in the States of Rajasthan and Gujarat. The State-wise distribution of the drainage basin is given below:

Table 16.1

Drainage Area of the Sabarmati Basin

State	Drainage Area
Rajasthan	4,124 sq. km.
Gujarat	17,550 ,,
Total	21,674 ,,

16.2 The Sabarmati basin is bounded on the north and north-east by the Aravalli hills, on the east by the ridge separating it from the Mahi basin, on the south by the Gulf of Cambay and on the west by the ridge separating it from the basins of minor streams draining into the Rann of Kutch and the Gulf of Cambay. The basin has a maximum length of 300 km. and maximum width of 105 km. at about half of its length. It is triangular shaped with the main river as the base and the source of the Watrak as the apex point.

THE RIVER SYSTEM

16.3 The Sabarmati is one of the major west-flowing rivers draining into the Gulf of Cambay.

It rises in the Aravalli hills at north latitude 24°40′ and east longitude 73°20′ in the Rajasthan State at an elevation of 762 metres. After traversing a course of about 48 km. in Rajasthan, the river enters the Gujarat State. At the 51st km. of its run, it receives the Wakal on the left near the village of Ghonpankhri. Flowing in a generally south-west direction, at the 67th km. of its run, it receives the Sei, from the right, near Mhauri and then the Harnav, from the left at about 103rd km. from the source. Beyond this confluence, the Sabarmati flows through the Dharoi gorge. Emerging from the gorge, it passes through the plains and is joined on its left at about 170 km. from its source by the Hathmati, a major tributary. Continuing to flow south-westwards, the river passes Ahmedabad at about 238 km. of its run and 65 km. downstream, another major tributary, the Watrak, joins it from the left. Flowing for a further distance of 68 km., the river outfalls into the Gulf of Cambay in the Arabian Sea.

The total length of the river from the head to its outfall into the sea is 371 km., of which about 48 km. are in Rajasthan and the remaining 323 km. in Gujarat.

16.4 The principal tributaries of the river are the Sei from the right and the Wakal, the Harnav, the Hathmati and the Watrak from the left. These are described briefly in the following paragraphs.

The Sei: Rising in the Aravalli hills in Rajasthan, the Sei flows south-west for a total distance of 95 km. to join the Sabarmati on its right. It drains an area of 946 sq. km.

The Wakal: Rising in the Aravalli hills in Rajasthan and flowing in a generally south-west direction for a total length of 88 km., the Wakal joins the Sabarmati from the left. It drains an area of 1,625 sq. km. The Manas is its main tributary.

The Harnav: Rising in the northern portion of the Kulalia hills of the Rajasthan ranges and flowing in a generally south-west direction for a total distance of 75 km., the Harnav falls into the Sabarmati from the left. It drains a total area of 972 sq. km. The Kaluri, the Belaun and the Kusumbi are its main tributaries.

The Hathmati: Rising in the south-west foothills of Rajasthan range in Gujarat State, the Hathmati flows in a generally south-west direction for a total distance of 105 km. to meet the Sabarmati on its left. This major tributary drains an area of 1,523 sq. km. The Ghuvai is its important tributary.

The Watrak: Rising in the Panchera hills in the Dungarpur district of Rajasthan and flowing generally in a south-west direction for a total distance of 248 km., the Watrak joins the Sabarmati from the left. The Watrak and its tributaries drain an area of 8,638 sq. km. The important tributaries of the Watrak are the Majhan, the Meshwa, the Khari and the Shedi.

CLIMATE

Seasons

16.5 During the year four distinct seasons occur in the basin. They are (i) winter, (ii) summer, (iii) monsoon and (iv) post-monsoon.

The winter season begins in December and continues till the end of February. January is the coldest month of the year. Clear bright weather, interspersed by brief spells of cloudy weather and accompanied by a little rain caused by western disturbances traversing north India is experienced during this part of the year. Winds blow mainly north-east.

From March onwards, the hot weather sets in and continues till the middle of June. Thunder-storms occur occasionally during this season. The winds are generally north-easterly.

The south-west monsoon normally sets in by the middle of June and continues to be active till September. 95% of the annual rainfall occurs during this period. Heavy showers generally occur in association with monsoon depressions from the Bay of Bengal and the Arabian Sea.

The south-west monsoon withdraws by about the middle of September and the weather clears up. Pleasant weather prevails till the end of December.

Rainfall

16.6 There are at present 42 reporting rain-gauge stations inside the basin. The Central Water & Power Commission has suggested the establishment of nine more stations to obtain a balanced distribution of gauges over the entire basin. Details of the proposed rain-gauge stations are given below:

Table 16.2

Proposed Rain-gauges

Proposed rain-gauges	Location (District)
(1) Paraoli	Udaipur
(2) Bansiwara	Udaipur
(3) Manpur	Udaipur
(4) Mezer	Sabarkantha
(5) Mirad	Sabarkantha
(6) Sadra	Sabarkantha
(7) Samlaji	Sabarkantha
(8) Omari	Mehsana
(9) Mansa	Mehsana

16.7 The average rainfall recorded at the existing rain-gauge stations has been published by the India Meteorological Department. The upper reaches of the basin receive a rainfall of over 900 mm. against about 650 mm. in the lower reaches. The average annual rainfall over the entire catchment is 785 mm. the rainfall during the monsoon months of June to September accounts for over 95% of the annual precipitation in the basin. The month-wise distribution of the normal rainfall in the basin is given below:

Table 16.3

Annual Rainfall in the Sabarmati Basin

Month	Normal rainfall (mm.)	Percentage of annual rainfall
April	1.8	0.23
May	9.0	1.15
June	84.4	10.76
July	318.2	40.54
August	233.7	29.78
September	114.4	14.57
October	10.4	1.33
November	4.2	0.55
December	1.3	0.17
January	2.6	0.33
February	2.8	0.86
March	1.8	0.23
Total	784.6	100.00

Temperature

16.8 In January, during the winter season, the mean minimum temperature varies from 11.2°C at Ahmedabad in the south to 8.6°C at Udaipur in the north, just outside the catchment. The higher elevations in the north experience lower temperatures. The lowest minimum temperatures ever recorded in 1920 and 1957 were 2.2°C and 1.1°C at Ahmedabad and Udaipur respectively.

During the summer season, May is generally the hottest month, when the mean maximum temperature ranges from 41.6°C at Ahmedabad to 39.2°C at Udaipur. The temperatures are higher in the plains (lower reaches) than in the hills (upper reaches). Maximum temperatures recorded at Udaipur and Ahmedabad are of the order of 44.4°C and 47.8°C in 1958 and 1916 respectively.

In the rainy and the post-monsoon seasons, the temperatures are moderate and are in the range, 26°C to 30°C at Ahmedabad.

Evaporation

16.9 Practically no data on evaporation is available for the Sabarmati basin. The India Meteorological Department has compiled evaporation data in respect of 30 departmental observatories and 42 agro-meteorological observatories with data covering more than five years. Observations at all these observatories are taken with the standard U.S. Evaporation Pan (Class 'A') covered with wire mesh. For the departmental observatories, the data pertains to the period 1959 to 1968 and is available month-wise, whereas the data for the agro-meteorological observatories pertains to the period 1961 to 1968 and has been presented for 12 periods into which the calendar year is divided for agro-meteorological purposes. The only departmental observatory located in the Sabarmati basin is at Ahmedabad.*

The evaporation losses from reservoir as assumed in the Sabarmati Project are given below:

Table 16.4

Assumed Evaporation Losses in Sabarmati Project

Name of the Project	Evaporation (cm.)		
	Monsoon	Non-Monsoon	Annual
Sabarmati**	38	145	183

From the figures shown in the above table it would appear that the assumed evaporation rates are lower than those indicated by the general meteorological conditions at the sites.

SOILS

16.10 No systematic soil survey of the Sabarmati basin has been carried out so far. The general data regarding the soils of India, however, indicate that the basin consists mainly of black, alluvial and sandy soils. Plate II shows the main soil types found in the basin.

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*Evaporation Data (India), India Meterological Deptt. (April, 1970).

**Project Report on the Sabarmati Reservoir Project, Govt. of Gujarat (1965).

16.11 The basin partly covers the districts of Dungarpur, Udaipur and Sirohi in Rajasthan and Sabarkantha, Banaskantha, Panchmahals, Mehsana, Ahmedabad and Kaira in Gujarat. The principal soil types found in the various districts in the basin are given below.*

Dungarpur and Udaipur: The eastern part of the districts has mixed red and black soils while the western part has red and yellow soils.

Sirohi: The entire district is a vast sandy plain with isolated hills and rock outcrops.

Sabarkantha: Medium black soils occur in the major part of the district, while 'goradu' soil (rich loam) is found in the western portion.

Panchmahals: The soils are somewhat different from those in the other districts, in that they are residual soils formed by the decomposition of granites and gneisses. The soils are of light colour, shallow and infertile, but those situated in the lower plains are darker, clayey and fertile.

Mehsana: Except for the western portion of the district which has sandy soils, the rest of the area is covered by 'goradu' loam.

Ahmedabad: Two types, namely black soil and 'goradu' soil (rich loam) occur and lie close to one another. Soils in the south-west are black and those in the northern and eastern portions are 'goradu'.

Kaira: Four types of soils, namely light reddish brown or 'gorau', medium or 'besar', black or 'kali' and alluvial or 'bhata' occur.

Banaskantha: Shallow sandy soils and sandy loams occur.

LAND USE AND AGRICULTURAL PRACTICES

16.12 State-wise land use details in the basin, as in 1967–68, the latest year for which statistics are available, are given in Table 16.5.

16.13 The culturable area in the basin is about 0.8 per cent of the total culturable area of India but the total cropped area in the basin is about 0.9 per cent of the total cropped area in the country.

Area under irrigated crops is about 16 per cent of the cropped area in the basin.

16.14 The general cropping pattern, State-wise is described below:

Rajasthan

Of the gross irrigated area of nearly 25,300 hectares, 43.5 per cent is under wheat, 28.5 per cent under barley and 5.9 per cent under cotton.

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*Soils of India by S. P. Raychaudhari, R. R. Aggarwal, N. R. Datta Biswas, S. P. Gupta and P. K. Thomas.

Table 16.5

Land Use Details in the Sabarmati Basin

(Thousand hectares)

Sl. No.	Item	Name of State		Total
		Rajasthan	Gujarat	
1	2	3	4	5
1.	Gross area	412	1,755	2,167
2.	Reporting area	398	1,679	2,077
3.	Area under forests	49	164	213
4.	Area not available for cultivation	144	172	316
5.	Culturable area	205	1,343	1,548
6.	Uncultivated culturable area	125	159	284
7.	Net area sown	80	1,184	1,264
8.	Area sown more than once	24	115	139
9.	Total cropped area	104	1,299	1,403
10.	Net area irrigated	21	195	216
11.	Gross area irrigated	25	199	224
12.	Percentage of net area sown to culturable area	39.0	88.2	81.7
13.	Percentage of net area irrigated to culturable area	10.4	14.5	14.0
14.	Percentage of net area irrigated to net area sown	26.8	16.5	17.1

On 700 hectares sugarcane is grown. Other irrigated crops are paddy, jowar, bajra, maize, gram, tur, condiments, spices, fruits, vegetables, groundnut, sesamum, rape, mustard, linseed, tobacco and fodder crops.

Food and non-food crops cover about 86.6 per cent and 13.4 per cent of the irrigated cropped area respectively.

Gujarat

Of the gross irrigated area of 199,300 hectares, about 31.8 per cent is under wheat, 14.5 per cent under cotton and 19.1 per cent under paddy. On 900 hectares sugarcane is grown. Other irrigated crops are jowar, bajra, maize, barley, gram, other pulses, condiments, spices, groundnut, rape, mustard, tobacco and fodder crops.

Food and non-food crops cover about 74.4 per cent and 25.6 per cent of the irrigated cropped area respectively.

Summing up, of the total irrigated area in the basin, 29.8 per cent is under wheat, 19.7 per cent under cotton, 13.1 per cent under paddy, 5.1 per cent under fodder, 3.2 per cent under barley, 1.6 per cent under sugarcane and rest under miscellaneous crops.

16.15 In Rajasthan, there are two main crop seasons, namely (i) kharif and (ii) rabi. The kharif crops are sown from June to August and harvested from September to December, depending on the crop. Important crops grown in this season are paddy, jowar, bajra, maize and millets. The rabi crops are sown from October to December and harvested from February to May. Important rabi crops grown are wheat, barley and gram. Sugarcane is sown from January to May and harvested from November to February. There is a wide variation in the cropping patterns followed in the various districts in the basin. In Udaipur district, a major portion of the cropped area is under the primary cereals viz., wheat, barley, rice and maize. Other crops are millets, gram, pulses, oil seeds and cotton. In the Dungarpur area also primary cereals occupy large areas. In Sirohi district, a large part of the cropped area is under millets. Wheat, barley, rice, maize, gram, pulses and oilseeds are also grown.

16.16 Like Rajasthan, Gujarat has two crop seasons, namely, (i) kharif and (ii) rabi. The kharif crops are sown in the period June-August and harvested from October-December. The rabi crops are sown in October-November and harvested in February-March. The crop pattern varies considerably within the region. In Banaskantha, bajra and jowar are the main crops and occupy large areas. The area under cash crops is negligible. Mehsana produces mostly coarse millets and pulses, while Sabarkantha has a sizable area under cotton and groundnut. In Panchmahals, which is a hilly district, more than three-fourths of the cultivated area is devoted to foodgrains. Rice and maize are the important crops followed by tur and gram. Kaira district has a well-diversified cropping pattern, important crops being rice, wheat, cotton and tobacco. Among the cereals, bajra is the important crop. In Ahmedabad, wheat is an important cereal, followed by rice.

REGIONAL ECONOMY

Population

16.17 On the basis of the 1971 Census* and the percentage of the area of each district within the basin to the district as a whole, the total population in the basin is about 4.77 millions. The State-wise distribution is as under:

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*Census Paper 1 of 1971 (Supplementary), Registrar-General (India).

Table 16.6

Population in the Sabarmati Basin

State	Population
Rajasthan	0.44 million
Gujarat	4.33 „
Total	4.77 million

There is no city of more than a lakh population in the basin, except Ahmedabad which has more than a million inhabitants. The average density of population in the basin is 220 persons per sq. km. It varies from region to region within the basin. The most densely populated district of Kaira has 340 persons per sq. km. while the district of Sirohi with 82 persons per sq. km. is at the other extreme. 81.3% of the population in the basin live in rural areas and the remaining 18.7% lives in cities and towns. The working force constitutes about 31.9% of the population. Nearly 53.2% of the working force are engaged as cultivators, 15.6% as agricultural labourers and the remaining 31.2% are employed on other activities.

Forests and Agriculture

16.18 Forests and agriculture are the mainstay of the people. Nearly 8.9% of the total area of the basin is covered with forests, which are mainly of the tropical variety and largely confined to the northern portion of the basin in the districts of Sirohi, Banaskantha, Sabarkantha and Mehsana. The area annually cropped in the basin is about 1.37 million hectares. Agriculture is generally rain-fed with relatively low yields, except for about 0.18 million hectares of irrigated area, which mainly grows wheat and cotton.

Power

16.19 The Central Water & Power Commission has conducted surveys to assess the hydroelectric potential of the Sabarmati basin which has been estimated at practically nil. At present, the demand for the electrification of towns and industries etc., is being met mainly by means of diesel and thermal power plants. These two big thermal stations are at Ahmedabad

(187 MW) and Dhuvaran (Cambay) of which Stage-I was started in 1960 and commissioned in the Third Plan period with a capacity of 254 MW. Work on the second stage (215 MW) is in progress and is expected to be completed by 1971–72.

Mineral Wealth

16.20 The principal minerals found in the basin are:*

Limestone: Of high grade crystalline variety occurs in Banaskantha district. It also occurs in Mehsana.

Fluoride: Which has important metallurgical uses in steel, ferro-alloys and aluminium industries, in Dungarpur district.

Bauxite: In Kaira district.

China clay: In Sabarkantha and Mehsana districts is of good plastic variety.

Fire clays: In Panchmahals district.

Pipe clays: Of light colour, plastic and interspersed with sandstones are found around Himatnagar and along the Hathmati banks.

Glass sand: In Mehsana district.

Manganese ore: In Banaskantha and Sabarkantha districts, but is not considered economical for exploitation.

Mineral oil and Natural gas: In the Cambay area and around Kalol, Nawagam, Mehsana and Kadi.

Industries

16.21 The industrial development in the basin has taken place mainly in the lower part of the basin. The important industries are:

Ahmedabad: Cotton textiles, silk and other fabrics, leather and leather goods, plastic and allied products, rubber and rubber goods, paper, cardboard and newsprint, glass and ceramics, bicycles and bicycle parts, automobiles and automobile parts, agricultural equipment, machine tools, metal tubes and conduits, machinery and machine parts, copper and brass, chemicals, inks, paints and varnishes, fertilisers, drugs and pharmaceuticals, soaps.

Vijapur: Cement and asbestos sheets, matches.

Kaira: Dairy products.

Cambay: Oil Refinery (Koyali).

Communications

16.22 The basin is served by a network of the Western Railway of

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*Techno-Economic Surveys of Gujarat and Rajasthan, NCAER.

Broad-gauge, Metre-gauge and Narrow-gauge lines. Some of the important lines are, Bombay-Baroda-Ahmedabad-Viramgam, Ahmedabad-Mehsana-Delhi and Nadiad-Petlad-Bhadran. The aggregate lengths of the different gauge lines, in the basin are:

Broad-gauge	125 km.
Metre-gauge	393 km.
Narrow-gauge	83 km.

The important National Highway connecting Delhi with Rajkot passes through the basin for a distance of 190 km. In addition, there is the National Highway connecting Bombay-Ahmedabad. 80 km. of this Highway lie in the basin.

There are several State Highways like those connecting Ahmedabad with Kapadvanj and Mehsana, Himatnagar with Khedbrahma and Mehsana etc. In addition, there are also district roads.

The river and its tributaries are not navigable.

The middle and the lower parts of the basin are well served with communications, whereas the upper part lacks communication facilities.

The economy of the basin, at present, largely depends on agriculture, which, in view of the very low rainfall and its uneven incidence, provides a low level of subsistence, except for limited areas where facilities for irrigation have been provided and where industries have developed. There is a keen demand in the basin for the full development of the available water resources.

WATER RESOURCES

Surface Waters

16.23 The water potential of the Sabarmati river basin has been assessed at different times by different authorities. The very first assessment was made by the First Irrigation Commission by grouping together all the west-flowing rivers, except the Narmada and the Tapi. As no records of flow were available, the Commission assessed the runoff, based on a co-efficient selected with regard to the rainfall and other conditions, and the co-efficient of actual flow determined in other catchments. This surface flow was assessed on the above basis as 230,784 m. cu. m.*

In 1949, when the basin-wise assessment of the water resources of the country was made on the basis of Khosla's empirical formula, the annual runoff of the Sabarmati basin had been assessed as 4,664 m. cu. m.**

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*Report of the Indian Irrigation Commission (1901-03).

**An appraisal of water resources by Dr. A. N. Khosla, UNESCO.

In 1960, the Central Water & Power Commission, while conducting the irrigation potential studies assessed the average annual runoff of the Sabarmati river system, based on 17 years' discharge data at Dharoi site, as 3,663 m. cu. m.*

16.24 There has been no planned or systematic observation of discharges on the Sabarmati and its tributaries. Some *ad hoc* and irregular observations have been made on the main river and on a number of tributaries in Gujarat State. The details of the existing gauge and discharge sites are given below.**

Table 16.7

Existing Gauge and Discharge Sites

Sl. No.	River/Tributary	Existing Gauge & Discharge site	Catchment Area up to the site in sq. km.
1.	Sabarmati	Dharoi	5,540
2.	Sabarmati	Ahmedabad	10,202
3.	Harnav	Abhapur	129
4.	Harnav	Khedbrahma	673
5.	Hathmati	Khandial	513
6.	Hathmati	Himatnagar	1,308
7.	Meshwa (including Khari)	Raipur	679
8.	-do-	Samlaji	239
9.	-do-	Raska Weir	2,634
10.	Watrak	Wadagam	793
11.	Watrak	Pahadia	1,041
12.	Watrak	Ratanpur	2,901
13.	Shedi	Padal	234

The data available at most of the sites is incomplete, inconsistent and undependable. Some sites have been working for short periods, but even for these periods, the data is not continuous. There is no gauge-discharge site below Ahmedabad on the Sabarmati, though the catchment area downstream of this site constitutes 53% of the total catchment area. Similarly, 67% of the catchment of the Watrak, which drains about 40% of the total Sabarmati catchment, is not being gauged. Thus there are only three gauge and discharge sites at Dharoi, Waghpur and Ahmedabad where by and large data is available since 1950. Waghpur has, however, discontinued discharge observations from 1962. At Dharoi, the velocities have been measured by using floats, and the discharges calculated after applying a correction factor to the surface velocity to obtain the mean velocity. The discharges at the Ahmedabad site have been measured after determining the velocities by current-meter observations and these can be taken as fairly accurate.

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*Report of Technological possibilities of irrigation projects in India, CW&PC (Unpublished).

**Report on the Sabarmati basin for assessment of surface water resources, CW&PC (Sept. 1969).

16.25 Observations at the existing sites being neither continuous nor systematic, the Central Water & Power Commission has suggested that these observations should be standardised and made continuous at the existing sites, and that nine additional gauge and discharge sites as detailed below should also be established:

Table 16.8

Proposed Additional Gauge and Discharge Sites

Sl. No.	River/Tributary	Proposed Gauge and Discharge site	Catchment Area up to the proposed site in sq. km.
1.	Sabarmati	Waghpur	8,726
2.	Sabarmati	Girand	19,772
3.	Harnav	Weir site at Naka	445
4.	Harnav	Marwada	862
5.	Hathmati	Hathmati dam at Fatepur	596
6.	Meshwa	Govindra	1,740
7.	Watrak	Wasne Bijrag	8,575
8.	Shedi	Kapadvanj	627
9.	Shedi	Bilodra	2,393

In the programme of Centrally sponsored key hydrological stations, the Central Water & Power Commission has proposed the inclusion of the gauge and discharge site at Dharoi on the Sabarmati. Besides, the Commission has suggested that two gauge and discharge sites namely (1) Sabarmati at Ahmedabad and (2) Meshwa near Matar may be maintained by the Gujarat State.

16.26 With the available discharge data, the Central Water & Power Commission has recently assessed the annual runoffs of the Sabarmati river system at 50%, 75% and 90% dependabilities as given in Table 16.9*

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*Report on the Sabarmati basin for assessment of surface water resources, Central Water and Power Commission (Sept. 1969).

Table 16.9

Annual Run-off of Sabarmati System

River	Site	Annual runoff on dependability		
		50%	75%	90%
		m. cu. m	m. cu. m.	m. cu. m
Sabarmati	Dharoi	563.42	358.99	257.61
Sabarmati	Waghpur	1,095.08	890.02	764.37
,,	Ahmedabad	1,279.32	909.70	708.73
Harnav	Up to confluence	128.76	86.73	64.97
Hathmati	-do-	234.07	151.07	109.80
Meshwa	-do-	390.24	273.17	210.59
Watrak	-do-	494.16	357.41	279.71
Shedi	-do-	446.42	323.93	253.16

Ground Waters

16.27 A portion of the Sabarmati basin lying to the east of east longitude 73° is underlain mostly by crystalline rocks and traps. Himatnagar sandstones occupy a linear strip extending roughly north to south from Himatnagar. To the west of east longitude 73°, the drainage of the river forms a part of the Cambay sedimentary basin. Along the major tributaries like the Watrak, alluvial soils are found.

16.28 Systematic investigations and studies of the ground water potential of the Sabarmati basin have not been made so far. Only in some parts of the Mehsana, Sabarkantha, Ahmedabad and Kaira districts, were some investigations and studies conducted recently.*

Investigations in Mehsana district over a total area of 6,400 sq. km. indicate that ground water occurs under water-table and confined conditions. Near the surface, the ground water occurs under water-table conditions and at depths under confined conditions. The quality of ground water deteriorates progressively from east to west. There is scope for limited development in the area which has been explored.

The area investigated in Sabarkantha district is underlain by pre-cambrian crystalline rocks, Himatnagar sandstones, lava flows (Deccan trap) alluvium and blown sand. The depth of the water-table varies from 2 to 20 m. except in the area lying between the rivers Sabarmati and Bokh where it goes down to as much as 35 m. In parts of the area underlain by traps in the near-surface zones, the underlying Himatnagar sandstones form potential aquifers. The water is of good quality and the feasibility of tapping the sandstones in selected parts has been confirmed.

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*Ground Water Resources of India, Status and Surveys, Prospects and Perspectives, Geological Survey of India, (August, 1970).

An area of about 1,800 sq. km. south of Ahmedabad has been investigated. It forms part of the Cambay basin and is underlain by alluvium, with tertiary rocks below. The water-table in this region lies at a depth between 10 to 20 metres. The quality of the near-surface ground water is generally good.

The Watrak sub-basin is underlain by crystalline rocks in the upper reaches, by Himatnagar sandstones, Bagh beds and Deccan trap in the middle reaches and by alluvium in the lower reaches. Ground water in the alluvial tract occurs both under water-table and artesian conditons. The depth of the water-table over large parts of the area ranges from 10 to 25 m. except in the vicinity of the Watrak river where it is about 10 metres in depth. The quality of water improves with the depth.

A characteristic feature of the artesian water in Kaira and Mehsana districts is the high temperature, ranging between 35°C and 42°C. The abnormally high temperatures of water at depths of over 200 m. will have to be taken into account before considering its fitness for direct application to irrigation. These temperatures are too high for plant tolerance and the water will have to be cooled.

There is thus a necessity for a systematic exploratory programme for a scientific, quantitative and qualitative assessment of the ground water resources. It will help in framing a rational plan for the development of water resources for various needs, which can be made only after full investigations.

EXISTING DEVELOPMENT

16.29 The Hathmati and Kharicut Canals Project is the oldest irrigation system in the basin. A 317 m. long weir across the river Hathmati at Himatnagar with a canal system to serve about 4,047 hectares in Sabarkantha district was constructed in the period 1870–74. Surplus waters of this canal system were diverted to the Khari river near Jenpur through the Bhujwa Channel. To utilise the extra supplies, a weir across the Khari at Raipur was built in 1880–84, with a canal system known as the Kharicut System to serve an additional area of 2,833 hectares. Later, in order to utilise more water, the Bokh Reservoir was created by the construction of the Limla dam, and the Bokh Feeder was built in 1909–10 to serve another 809 hectares.

16.30 The other pre-Plan projects in the basin are the Meshwa Canal System (Raska Weir), the Ahmedabad Water Supply Scheme and the Nani Fatewadi Canal System on the Sabarmati.

16.31 The Raska Weir across the Meshwa with its canal system was built during the period 1947–50 at a cost of Rs. 5.4 million. The concrete weir across the river is 157 m. long. The main canal with a discharge of 14.16 cumecs is 14.5 km. long and irrigates about 7,284 hectares in the Kalambadhi area.

16.32 The source of water supply to Ahmedabad City is the Sabarmati. The withdrawal from the river in 1951–52 which was of the order f 0.85 cumecs increased to 1.84 cumecs in 1964–65. The demand is in-reasing every year. To augment the water supplies to Ahmedabad City d the State's new capital, the Gujarat Government are contemplating construction of a new barrage at Vasna across the Sabarmati, as a t of the Sabarmati Reservoir Project.

16.33 The Nani Fatewadi Canal takes off from the Sabarmati near e village of Fatewadi, about 9.6 km. downstream of Ahmedabad. The area under the command of this canal is 13,622 hectares.

16.34 One major and a number of medium projects were taken up for construction in the Sabarmati basin during the Plan periods. The salient features of the projects completed in the basin in the pre-Plan and Plan periods are shown in Appendix 16.1. The important ones are briefly described below:

16.35 *The Hathmati Reservoir Project*: The only major project in the basin consisting of an earth rock-fill dam across the river Hathmati near Fatehpur village in Sabarkantha district is the Hathmati reservoir with a maximum height of 23.5 m., a gross storage of 161.5 m. cu. m., and a live storage of 154.8 m. cu. m. The 191.2 km. long canal system irrigates an area of 37,604 hectares. Work on the project was started in 1959 and completed during 1968–69 at a cost of Rs. 54.46 million.

16.36 *The Moti Fatehwadi Canal System*: The project comprises a combined regulator on the Sabarmati river for the two canal systems of Moti Fatewadi and Nani Fatewadi near the village of Fatewadi in Ahmedabad District. It irrigates about 12,950 hectares of land. Work on the project was started in 1954 and completed in 1966–67 at a cost of Rs. 7.23 million.

16.37 *The Harnav River Scheme*: It consists of a pick-up weir across the Harnav, 13 km. upstream of Khedbrahma, and a canal system, at a total cost of Rs. 5.24 million. The canal on the left bank with a full supply discharge of 8.5 cumecs irrigates an area of 2,670 hectares in

Sabarkantha district. The project was taken up for construction during 1955–56 and completed in 1969.

16.38 *The Karol Tank*: An earth dam near village Karol in Sabarkantha district has been constructed across the Bokh to irrigate an area of 1,210 hectares. The project, started in 1956, was completed in 1969 at a cost of Rs. 1.2 million.

16.39 *The Shamlaji (Meshwa Reservoir) Project*: A 35.66 m. hig dam across the river Meshwa near the village of Shamlaji in Sabarkant district has been built to create a reservoir of gross storage capacity 2,900 m. cu. m. A 41 km. long canal taking off on the left, irriga 23,900 hectares. The project was taken up for construction in 1958- and completed in 1969 at a cost of Rs. 31.43 million.

During the Third Plan, no projects have been taken up in the basin.

16.40 In the Annual Plan period (1966–69), one project, the Sei diversion project has been taken up by Rajasthan State. This project provides for the construction of a 24.2 m. high dam across the river Sei in Udaipur district to divert its waters to the Jawai river through a 5,784 m. long tunnel for feeding the existing Jawai reservoir. The project, costing Rs. 15.00 million, was started in 1968 and will provide irrigation to an area of 8,920 hectares (Appendix 16.2).

16.41 Besides the major and medium projects in the Sabarmati basin, minor schemes comprising tanks and wells irrigate a large area. The details of the area irrigated by various sources like canals, tanks, wells etc. during the year 1967–68, State-wise, in the basin are given below:

Table 16.10
Source-wise Irrigation

(Thousand hectares)

Sl. No.	Source of irrigation	Area in State of Rajasthan	Area in State of Gujarat	Total area
1.	Canals	—	40.0	40.0
2.	Tanks	4.2	5.4	9.6
3.	Tubewells	—	8.5	8.5
4.	Wells	16.7	139.3	156.0
5.	Other sources	0.5	1.6	2.1
	Total	21.4	194.8	216.2

By the end of 1968–69, the area under minor schemes increased by about 7,300 hectares.

16.42 The Central Water & Power Commission, has in its recent studies estimated that the ultimate utilisation by all major and medium projects in the basin up to the beginning of the Fourth Plan is of the order of 1,220.47 m. cu. m. According to the data supplied by the Gujarat Government, there are 51 minor schemes in operation and 14 under construction. Information in respect of minor schemes in Rajasthan is not available. In the absence of the statistics for minor schemes, utilisation by such projects has been estimated by the Commission on the basis of the total area irrigated under these sources. On completion and full development the minor projects under operation and construction in 1968–69 would use about 2,076 m. cu. m. including reservoir losses. Thus, on completion and full development the major, medium and minor projects under operation and construction in 1968–69 would use about 3,296.47 m. cu. m. of which 1,470.47 m. cu. m. is from surface waters and 1,826 m. cu. m. from ground waters.

16.43 A large number of industries is located in and around Ahmedabad, but the data on the industrial use of the Sabarmati waters is not readily available. The demand is expected to grow in the future and to meet the growing needs for domestic and industrial use, the State Government proposes to construct the Sabarmati Reservoir Project.

16.44 With the concentration of several industries, the danger of water pollution by industrial wastes in the lower reaches of the river needs to be guarded against.

FUTURE DEVELOPMENT

16.45 Only one major project viz. the Sabarmati Reservoir Project is proposed in the basin, for the Fourth Plan. The project, at a cost of Rs. 165.5 million, envisages the construction of (i) a 1,227.73 m. long composite dam across the river Sabarmati at Dharoi, about 153 km. to the north of Ahmedabad City, (ii) canals taking off from the dam on either bank for irrigating an area of 39,650 hectares in the Mehsana and Sabarkantha districts and (iii) a barrage across the Sabarmati at Vasna, just downstream of Ahmedabad. It will also firm-up the existing irrigation under the Fatewadi Irrigation Scheme through the Vasna barrage and will provide water to Ahmedabad City and to the Gandhinagar township. The water utilisation contemplated under the project is of the order of 655 m. cu. m., including reservoir losses. Some details of the project are given in Appendix 16.3.

16.46 The area under minor schemes is expected to increase by about 48,380 hectares during the Fourth Plan period requiring nearly 548 m. cu. m. of water, including reservoir losses.

16.47 Thus, the additional utilisation by the Fourth Plan major, medium and minor projects would be of the order of 1,213 m. cu. m. benefiting an area of 88,040 hectares. On the completion and full development of Fourth Plan projects, about 4,509 m. cu. m. of waters (2,201 m. cu. m. of surface waters + 2,308 m. cu. m. of ground waters) would have been used for irrigating a total area of 379,847 hectares. Water resources in the basin are being fully utilised at present.

16.48 The State Governments have not indicated the new projects proposed to be taken up in future. If the Navagam high level canal and the Kadana high level canal materialise, part of the area being irrigated at present by the Sabarmati waters will get transferred to the two high level canal commands and be fed by the Narmada and Mahi waters. The extension of irrigation in the basin, at that stage, would be effected by using the released Sabarmati waters.

FLOODS, WATERLOGGING AND DRAINAGE

16.49 The Sabarmati is purely rain-fed, and carries large quantities of water during the monsoon period. The flow in the lower reaches of the river during the non-monsoon period is chiefly derived from regeneration. The disparity in the maximum and minimum flows is very marked.

The occurrence of heavy floods is not a regular feature of the basin. There are, however, occasions when floods do occur and cause damage to life and property. Areas east, west and south-west of Sabarmati experience floods relatively more often. These floods, however, are beneficial in certain areas as they provide the necessary moisture for raising crops and help in suppressing salts in the soil.

A maximum flood discharge of 11,575 cumecs has been recorded in 1950 at Ahmedabad. The minimum flow is practically nil.*

In the basin, there has really been no serious flood problem and in consequence, no large scale flood control measures have been undertaken. However, a number of small schemes of a local nature consisting mostly of retaining walls and embankments have recently been constructed in the region, and some more are proposed by the State authorities.

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*Report of the High Level Committee on Floods, Ministry of Irrigation & Power (1958).

SOIL CONSERVATION

16.50 The Sabarmati basin is in a low rainfall region and is subject o heavy wind erosion. On the rocky hills and plateaus, the soil is hallow, eroded and devoid of vegetation, as the top soil has been lown away or washed down. The rainfall being erratic and the wind elocities high, intensive erosion is taking place and poses a serious roblem.

Improper land use accelerates soil erosion and leads to the formation f gullies, and, ultimately, ravines. It is estimated that nearly 0.4 million ectares of land in Gujarat, a considerable portion of which lies in the abarmati, Meshwa and Watrak valleys, are disfigured by ravines. A rge area in Rajasthan is similarly affected. The control and reclamation f ravines has to be achieved by the construction of marginal bunds for version channels in the catchment feeding the ravines; by the consuction of check dams or gully plugs in the ravines at proper intervals; y toning down or easing the steep slopes or the gully banks to the angle of natural slopes and sodding the slopes with soil-binding vines and grasses, by planting suitable fast-growing trees and shrubs along the banks of the rivers and the cut-up areas; by constructing wire crate-walls within the khads; and by the introduction of better farm practices and soil conservation measures in the table lands of the catchment.

16.51 The basin has hardly 8.9% of its area under forests, which is low compared to the all-India average and the standards laid down in the Forest Policy Resolution of 1952. Afforestation of the catchment is called for to reduce the hazards of erosion.

16.52 Practically no data is available regarding the silting of existing reservoirs and tanks in the basin. For the conservation of river supplies, and especially of the storage capacities created in the reservoirs, it is important that soil conservation measures should be taken up, which may be broadly classified as follows:

(i) Afforestation in new areas as well as in existing forests either denuded or where replacement is needed;

(ii) Terracing and contour bunding and construction of field bunds on agricultural lands;

(iii) Pasture development and protection of marginal and sub-marginal lands; and

(iv) Stream control measures including fringe afforestation and stream bank control.

No scheme in the Sabarmati basin has been included under the Centrally sponsored programme of soil conservation in the catchments of major river valley projects.

GENERAL

16.53 The Sabarmati and its tributaries are an inter-State rive system, flowing through the States of Rajasthan and Gujarat. A numbe of projects have already been constructed in the basin. One mediu scheme is under construction in Rajasthan, but the approach all alon has been to consider the projects in the light of the benefits which they will bring to the concerned State. In regard to the distribution and utilisation of Sabarmati waters, no agreement exists between Gujarat an Rajasthan.

16.54 The number and distribution of rain-gauge stations should b reviewed and new stations to fill up gaps should be established. It important that the daily rainfall data for all these stations be publishe on a monthly basis, preferably by sub-basins.

16.55 A network of evaporation-measuring stations in the basin, particularly at the sites of existing and proposed reservoirs needs to be established.

16.56 Gauge and discharge observations at the various sites in the basin should be continued on a permanent basis, to obtain data essential not only for the regulation to the best advantage, of available river water in any year.

16.57 Systematic and scientific exploratory work is needed for a quantitative and qualitative assessment of groundwater resources, so that these resources may be exploited in a rational way, either independently or in conjunction with surface waters.

16.58 There is need for inter-State co-operation and agreement in respect of carrying out soil conservation measures and conserving the storage capacities of existing and proposed reservoirs in the basin.

16.59 It is necessary that systematic studies be made of the sediment carried by the river waters, for working out dead storage and the life of reservoirs. This will also help soil conservation works in the basin.

SALIENT FEATURES OF THE BASIN OF THE LUNI AND OTHER RIVERS OF SAURASHTRA AND KUTCH

(i) Source	The Luni	South of Pilwa village in the Nagaur district (Latitude 26°37′N, Longitude 74°38′E).
	The Shetrunji	Near Dalkhania village in the Amreli district (Latitude 21°13′N, Longitude 70°54′E).
	The Bhadar	South-east of Aniali village in the Rajkot district (Latitude 22°7′N, Longitude 71°17′E).
	The Machhu	Near Bhadla village in the Rajkot district (Latitude 22°11′N, Longitude 71°6′E).
	The Rupen	East of Kodram village in the Mehsana district (Latitude 23°59′N, Longitude 72°40′E).
	The Saraswati	North-east of Jalotr village in the Banaskantha district (Latitude 24°12′N, Longitude 72°38′E).
	The Banas	East of Sirohi in the Sirohi district (Latitude 24°54′N, Longitude 72°53′E).

(ii) Length	The Luni	482 Km.	299 miles
	The Shetrunji	182 Km.	113 miles
	The Bhadar	198 Km.	132 miles
	The Machhu	140 Km.	87 miles
	The Rupen	154 Km.	96 miles
	The Saraswati	144 Km.	89 miles
	The Banas	230 Km.	143 miles

(iii) Drainage area	Rajasthan	193,392 Sq. Km.	74,668 Sq. miles
	Gujarat	128,420 Sq. Km.	49,583 Sq. miles
	Diu	39 Sq. Km.	15 Sq. miles
	Total	321,851 Sq. Km.	124,266 Sq. miles

(iv) Population (1971 Census)	21.82 millions	
(v) Density of population	68 per Sq. Km.	176 per Sq.mile
(vi) Average annual runoff of the basin	12,278 m. cu. m.	9.95 MAF
(vii) Culturable area (1967-68)	23,447 thousand hectares	57,940 thousand acres
(viii) Net area sown (1967-68)	14,159 „	34,988 „
(ix) Gross area sown (1967-68)	14,807 „	36,590 „
(x) Net area irrigated (1967-68)	1,093 „	2,701 „
(xi) Gross area irrigated (1967-68)	1,216 „	3,005 „
(xii) Area irrigated after completion & full development of 4th Plan projects (excluding the Rajasthan Canal Project)	1,731 „	4,277 „
(xiii) Water utilisation including reservoir losses	M. cu. m.	MAF

(a) On completion & full development of major, medium and minor projects under operation and construction in 1968-69	Surface water	3,812	3.09
	Ground water	8,389	6.80
	Total	12,201	9.89
(b) On completion and full development of Fourth Plan projects	Surface water	4,711	3.82
	Ground water	12,652	10.26
	Total	17,363	14.08

CHAPTER XVII

BASIN OF THE LUNI AND OTHER RIVERS OF SAURASHTRA AND KUTCH

The basin extends over an area of 321,851 sq. km., and lies between east longitudes 68°7′ and 75°50′ and north latitudes 20°40′ and 29°25′. Located in Western India, it covers large areas in the States of Rajasthan and Gujarat. The State-wise distribution of the drainage basin is given below:

Table 17.1

Drainage Area State-wise

State/Union Territory	Drainage area in sq. km.
1	2
Rajasthan	193,392
Gujarat	128,420
Diu	39
Total	321,851

17.2 The basin is bounded on the north and east by the ridge separating it from the Indus, the Ganga and the Sabarmati basins, on the south by the Arabian Sea and on the west by Pakistan. The basin is irregular in shape and has a maximum length of 1,045 km. in a NE-SW direction and a maximum width of 470 km. in a NW-SE direction.

THE RIVER SYSTEM

17.3 Of the many rivers in the basin, the more important are the Luni, the Shetrunji, the Bhadar, the Machhu, the Rupen, the Saraswati and the Banas. The chief characteristics of the rivers flowing in Rajasthan is that after flowing for some distance they finally disappear in the desert sands. The rivers of the Saurashtra region have a common apex south-east of Rajkot from where most of the rivers originate and flow outwards radially.

The more important rivers in the basin are described in the following paragraphs:

17.4 *The Luni,* rises south of Pilwa village in the Nagaur district of Rajasthan at an elevation of 550 m. at north latitude 26°37′ and east longitude 74°38′ and flows in a generally south-westerly direction up to the village of Govindgarh whereafter it turns to the right and flows in a north-westerly direction up to the village of Alhiawas. The river then turns to the left and flows in a generally south-westerly direction up to village Samdari. The important tributaries which join the Luni in this reach are the Mitri from the right and the Litri, the Bandi and the Sukri from the left. Further down the river turns to the right and flows in an almost westerly direction. Near the village of Gamesra, the Luni again changes direction and assumes a generally south-westerly course. About 10 km. north of Gandap village it receives its most important tributary, the Jawai, from the left. The Jawai irrigation project has been constructed across this tributary in the Pali district for irrigating an area of 7,690 hectares. 11 km. further down the Sagi joins it from the left. The river finally disappears in the Great Rann of Kutch. The Luni has a total length of 482 km.

17.5 *The Shetrunji,* rises near the village of Dalkania in the Amreli district of Gujarat at an elevation of 300 m. at north latitude 21°13′ and east longitude 70°54′ and flows in a generally north-easterly direction for a length of 48 km. when it receives the Chatli from the left. It then turns to the right and flows in a generally easterly direction for another 134 km. to outfall into the Gulf of Cambay, south-east of Talaja. The Shetrunji drains an area of 5,514 sq. km. The Shetrunji (Palitana) project has been constructed across the river near Palitana town in the Bhavnagar district for irrigating an area of 34,804 hectares.

17.6 *The Bhadar,* rises south-east of the village of Aniali in the Rajkot district of Gujarat at an elevation of 250 m. at north latitude 22°7′ and east longitude 71°17′ and flows in a generally south-westerly direction for a total length of 198 km. to outfall into the Arabian Sea near Navibandar. The Moj is its most important tributary and joins from the right near Upleta. The Bhadar drains a total area of 7,094 sq. km.

17.7 *The Machhu,* rises near Bhadla in the Rajkot district of Gujarat at an elevation of 275 m. at north latitude 22°11′ and east longitude

71°6′ and flows in a generally northerly direction for a total length of 140 km. to join the Little Rann of Kutch near the village of Maliya. The Machhu irrigation project is under construction across the river near the village of Jodhpur about 10 km. from Morui. The project has been taken up in two stages. Stage I will irrigate an area of 6,760 hectares and stage II 7,689 hectares. The Machhu river drains a total area of 2,515 sq. km.

17.8 *The Rupen,* rises east of the village of Kodram in the Mehsana district of Gujarat at an elevation of 250 m. at north latitude 23°59′ and east longitude 72°40′ and flows in a generally south-westerly direction for a total length of 154 km. to join the Little Rann of Kutch south-west of village Kuwar. It drains an area of 3,999 sq. km.

17.9 *The Saraswati,* rises north-east of the village of Jalotr in the Banaskantha district of Gujarat at an elevation of 450 m. at north latitude 24°12′ and east longitude 72°38′ and flows in a generally south-westerly direction for a total length of 144 km. to join the Little Rann of Kutch south-west of the village of Raplu. The Saraswati irrigation project is under construction across the river near Patna town in the Mehsana district. The project will provide irrigation to 8,742 hectares. The Saraswati drains an area of 2,934 sq. km.

17.10 *The Banas,* rises east of Sirohi town in the Sirohi district of Rajasthan at an elevation of 500 m. at north latitude 24°54′ and east longitude 72°53′ and flows first in a south-easterly direction for a length of 17 km. up to the village of Jharoli. Thereafter, it assumes a south-westerly direction and receives from the right its major tributary, the Sipu, near the village of Bhadoth. The river continues to flow in a south-easterly direction and finally drains into the Little Rann of Kutch west of the village of Ved. The Banas (Dantiwada) Project has been constructed across the river near the village of Dantiwada in the Banaskantha district. The project will irrigate 44,517 hectares on full development. The Banas drains an area of 8,674 sq. km. and has a total length of 230 km.

17.11 The details of the other important rivers in the basin are given in Table 17.2.

CLIMATE

17.12 During the year, four distinct seasons occur in the Basin. They are (i) winter, (ii) summer, (iii) monsoon and (iv) post-monsoon. The winter season begins in November and continues till the end of February.

Table 17.2
Particulars of Other Sourashtra Rivers

Sl. No.	Name of the river	Source					Length in km.
		Place	District	Latitude	Longitude	Elevation	
1	2	3	4	5	6	7	8
1.	Bhogava	Near Bhimora	Surendranagar	22°22′	71°12′	275	140
2.	Bhadar	East of Aniali	Surendranagar	22°8′	71°15′	250	145
3.	Keri	West of Aniali	Rajkot	22°8′	71°22′	225	98
4.	Kalubhar	South-west of Nilvala	Amreli	21°53′	71°14′	200	90
5.	Bagad	South of Iavej	Bhavnagar	21°19′	71°46′	150	40
6.	Valan	East of Gadhagra	Bhavnagar	21°17′	71°32′	150	42
7.	Rawal	North of Dudhala	Junagadh	21°12′	71° 7′	300	54
8.	Machundri	West of Dudhala	Junagadh	21° 9′	70°58′	300	56
9.	Singavada	Near Sasa	Junagadh	21°13′	70°48′	300	60
10.	Saraswati	South-west of Sasa	Junagadh	21° 8′	70°42′	150	58
11.	Megal	East of Chandawari	Junagadh	21°12′	70°29′	150	42
12.	Ojat	North of Sarkala	Amreli	21°15′	70°50′	300	132
13.	Wartu	Near Gunra	Jamnagar	22° 2′	69°58′	150	74
14.	Ghi	West of Bhangor	Jamnagar	22° 8′	69°45′	80	34
15.	Fuljar	North of Bhangor	Jamnagar	22°10′	69°50′	125	28
16.	Sasoi	North-east of Gunra					
17.	Rangmati	North-west of Chotar	Jamnagar Jamnagar	22° 5′ 22°10′	70° 4′ 70°12′	150 150	50 52
18.	Und	South of Nikara	Jamnagar	22°10′	70°33′	145	76
19.	Aji	South-east of Vadali	Rajkot	22°10′	70°56′	160	122
20.	Phulka	West of Ankevalia	Surendranagar	22°50′	71°23′	130	44
21.	Bambhan	East of Anandpur	Surendranagar	22°35′	71°15′	145	80
22.	Rukmawati	North of Daisara	Bhuj	23°10′	69°30′	155	48
23.	Kankawati	West of Magwana	Bhuj	23°13′	69°19′	150	56
24.	Naiera	North of Roha	Bhuj	23°17′	69°15′	145	58
25.	Miti	South-west of Nakhtarana	Bhuj	23°20′	69°10′	145	76

January is generally the coldest month of the year. Clear bright weather interspersed by brief spells of cloudy weather and accompanied by a little rain caused by western disturbances traversing North India, is experienced during this part of the year. The winds blow mainly from north to south.

From March onwards the hot weather sets in and continues till June. Thunderstorms occur very rarely during this season. The winds blow generally from north-west to south-east.

The south-west monsoon sets in by the middle of June and continues to be active till September. 92% of the annual rainfall occurs during this period. Heavy rains occur in association with monsoon depressions from the Bay of Bengal and the Arabian Sea.

The south-west monsoon withdraws by about the middle of September and the weather clears up. Pleasant weather prevails till the end of December.

Rainfall

17.13 There are at present 218 reporting rain-gauge stations inside the basin. The density works out to one station for every 1,599 sq. km. The number of gauges is, therefore, still insufficient, especially in the non-desert areas. The establishment of additional raingauges to obtain a balanced distribution over the entire basin is suggested. In selecting the locations for new raingauges, care should be taken to ensure that all the areas in the basin are suitably represented. The rainfall data of all the existing raingauge stations are being observed and printed by the rainfall registration authorities of the concerned States. This data appears in the annual volumes of the Daily Rainfall of India compiled and issued by the India Meteorological Department. Such volumes are available since 1891. A major part of the basin receives a rainfall of less than 600 m. The monthly and annual normals of rainfall in the various districts lying in the basin are given in Table 17.3.

Temperature

17.14 In January during the winter season, the mean minimum temperature over the catchment varies between 17.5°C and 22.5°C. The northern portions of the basin experience lower temperatures than the southern.

June is generally the hottest month during the summer season. The mean temperature over the basin varies from 27.5°C to 30°C. At places maximum temperatures of 45°C to 46°C have also been recorded. In the desert areas higher temperatures are experienced.

Table 17.3

Annual Rainfall in the Basins of Luni and Other Rivers

Sl. No.	State/District	Month-wise Normal Rainfall in mm.												Annual Normal Rainfall in mm.
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Rajasthan													
1.	Ganganagar	9.7	9.8	6.8	5.3	5.5	27.4	77.4	73.1	31.4	3.2	0.3	3.8	253.7
2.	Bikaner	3.9	6.1	4.1	4.2	10.2	25.1	78.0	89.5	33.0	5.9	0.4	3.5	263.7
3.	Churu	8.6	6.6	5.3	4.2	9.9	34.8	101.0	95.2	49.4	5.2	1.2	4.1	325.5
4.	Jhunjhunu	11.1	9.4	8.3	5.4	13.5	48.4	141.3	125.7	65.8	8.5	1.9	5.2	444.5
5.	Sikar	14.1	7.2	7.3	3.9	10.9	37.3	160.9	137.5	74.4	5.8	1.7	5.1	466.1
6.	Nagaur	6.2	6.0	4.9	3.4	12.1	37.3	127.6	127.9	52.1	5.6	1.3	4.2	388.6
7.	Jaipur	11.5	9.0	5.6	3.5	10.0	50.3	180.0	180.7	81.8	8.8	1.8	5.2	548.2
8.	Ajmer	5.5	5.0	4.3	2.7	10.3	50.9	172.8	181.3	77.6	11.1	2.7	3.1	527.3
9.	Udaipur	7.7	3.3	3.0	1.8	8.1	66.3	219.5	194.0	104.3	9.8	4.8	1.9	624.5
10.	Jodhpur	4.4	5.0	3.1	2.6	8.4	28.9	97.3	122.6	39.8	4.0	1.0	1.6	318.7
11.	Jalore	2.9	4.5	1.9	1.6	5.5	39.5	151.7	155.2	50.3	6.2	0.8	1.5	421.6
12.	Pali	3.9	4.9	2.5	2.2	9.8	43.3	151.5	190.1	73.7	5.6	1.3	1.6	490.4
13.	Sirohi	4.2	5.2	1.7	2.5	12.0	57.7	238.1	226.3	76.3	9.2	3.0	2.2	638.4
14.	Jaisalmer	2.2	4.2	1.9	1.3	3.2	10.1	54.8	72.2	12.5	0.5	0.5	0.6	164.0
15.	Barmer	2.8	3.6	2.5	1.6	6.6	19.4	87.3	113.1	33.7	3.6	0.6	1.1	275.9

Table 17.3—contd.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Gujarat													
16.	Banaskantha	2.6	4.2	1.7	1.1	8.5	53.0	248.8	211.8	82.0	8.6	2.5	1.7	626.5
17.	Mehsana	2.0	2.0	1.7	1.1	5.7	62.9	272.9	166.9	82.7	5.8	3.4	1.9	609.0
18.	Ahmedabad	1.5	1.4	1.4	1.9	9.5	78.7	266.0	153.3	94.4	12.1	4.7	0.9	625.8
19.	Surendranagar	1.7	1.3	1.4	1.6	6.4	73.6	217.8	114.1	73.5	9.7	4.7	1.0	506.8
20.	Bhavnagar	2.2	1.6	1.6	7.0	8.9	99.5	223.6	116.5	100.4	24.5	6.2	1.3	593.3
21.	Amreli	1.7	2.1	0.9	7.4	5.5	87.1	193.1	95.6	78.9	20.2	6.7	1.7	500.9
22.	Junagadh	1.6	2.3	1.8	2.0	6.6	119.8	272.2	118.3	78.0	15.7	3.0	1.9	623.2
23.	Rajkot	1.2	2.0	1.7	2.7	9.1	91.1	252.2	125.6	81.8	16.9	4.0	1.4	589.7
24.	Jamnagar	1.1	2.1	1.7	0.5	5.6	61.9	228.3	101.3	57.0	8.1	2.1	1.4	471.1
25.	Kutch	1.8	3.5	0.9	0.7	4.3	36.8	150.9	83.0	32.5	4.1	2.0	1.7	322.2

Source: Memoirs of the India Meteorological Department, Vol. XXXI, Part III.

In the rainy and post-monsoon seasons, the temperatures are moderate and are in the range of 27.5°C to 30°C.

Evaporation

17.15 Practically no data on evaporation is available for the basin. The India Meteorological Department has compiled the evaporation data in respect of 30 departmental observatories scattered all over the country possessing data for more than five years. Of these, four are departmental observatories located at Bikaner, Jodhpur, Erinpura and Okha and three are agro-meteorological observatories located at Virangam, Jamnagar and Junagadh lying in the basin.*

SOILS

17.16 No systematic soil survey of the basin has been carried out so far. The general data regarding the soils of India, however, indicate that the basin consists mainly of grey brown, desert, alluvial and sandy soils. The principal soil types found in the various districts in the basin are given below:**

Table 17.4
Soils in the Basins—District-wise

Sl. No.	District	Type of soil
1	2	3
	Rajasthan	
1.	Ganganagar	Desert and chestnut brown (alluvial)
2.	Bikaner	Desert
3.	Churu	Desert
4.	Jhunjhunu	Chestnut brown (alluvial), grey brown and desert
5.	Sikar	Alluvial, grey brown and desert
6.	Nagaur	Grey brown
7.	Jaipur	Alluvial
8.	Ajmer	Grey brown and mixed red and black
9.	Udaipur	Red and yellow
10.	Jodhpur	Grey brown
11.	Jalore	Grey brown and desert
12.	Pali	Grey brown and desert
13.	Sirohi	Grey brown and desert
14.	Jaisalmer	Desert
15.	Barmer	Desert

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*Evaporation Data (India), India Meteorological Department, April, 1970.

**Indian Crop Calendar, Ministry of Food, Agriculture, C.D. and Co-operation (1967).

Table 17.4—contd.

Sl. No.	District	Type of soil
	Gujarat	
16.	Banaskantha	Deltaic alluvium, grey brown and desert
17.	Mehsana	Deltaic alluvium, grey brown and desert
18.	Ahmedabad	Grey brown
19.	Surendranagar	Deltaic alluvium and grey brown
20.	Bhavnagar	Coastal alluvium, deltaic alluvium and grey brown
21.	Amreli	Deltaic alluvium
22.	Junagadh	Deltaic alluvium and coastal alluvium
23.	Rajkot	Deltaic alluvium
24.	Jamnagar	Deltaic alluvium
25.	Kutch	Deltaic alluvium, grey brown and alluvial

LAND USE AND AGRICULTURAL PRACTICES

17.17 State-wise land use details in the basin in 1967–68, the latest year for which the statistics are available are given below:

Table 17.5
Land Use Details in the Basins

('000 hectares)

Sl. No.	Item	Name of the State/U.T.			Total
		Rajasthan	Gujarat	Diu	
1.	Gross area	19,339	12,842	4	32,185
2.	Reporting area	19,185	12,489	4	31,678
3.	Area under forests	189	605	—	794
4.	Area not available for cultivation	3,162	4,272	3	7,437
5.	Culturable area	15,834	7,612	1	23,447
6.	Uncultivated culturable area	7,797	1,491	—	9,288
7.	Net area sown	8,037	6,121	1	14,159
8.	Area sown more than once	312	336	—	648
9.	Total cropped area	8,349	6,457	1	14,807
10.	Net area irrigated	413	680	—	1,093
11.	Gross area irrigated	496	720	—	1,216
12.	Percentage of net area sown to culturable area	50.8	80.4	100	60.4
13.	Percentage of net area irrigated to culturable area	2.6	8.9	—	4.7
14.	Percentage of net area irrigated to net sown area	5.1	11.1	—	7.7

17.18 The culturable area in the basin is about 12.0 per cent of the total culturable area of India. The total cropped area in the basin forms 9.1 per cent of the total cropped area in the country. The area under irrigated crops is about 8.3 per cent of the cropped area in the basin. The general cropping pattern State-wise is described below:

Rajasthan

Of the gross irrigated area of nearly 495,800 hectares, 42.6 per cent is under wheat, 16.9 per cent under barley, 7.9 per cent under cotton, 5.9 per cent under gram, 1.6 per cent under maize and rest under other crops. The other irrigated crops are rice, jowar, bajra, sugarcane, other pluses, tur, condiments, spices, fruits, vegetables, groundnut, sesamum, rape, mustard, tobacco and fodder crops. Food and non-food crops cover about 79.7 per cent and 20.3 per cent of the irrigated cropped area respectively.

Gujarat

Of the gross irrigated area of 720,300 hectares, 34.8 per cent is under wheat, 16.1 per cent under cotton, 6.5 per cent under rice, 2.8 per cent under sugarcane and the rest under other crops. The other irrigated crops are maize, barley, gram, jowar, bajra, condiments, spices, rape, mustard, tobacco and fodder crops. Food and non-food crops cover about 66.4 per cent and 33.6 per cent of the irrigated cropped area respectively.

17.19 Summing up, of the total irrigated area in the basin, nearly 38 per cent is under wheat, 12.8 per cent under cotton, 7.3 per cent under barley, 4 per cent under rice, 2.6 per cent under gram, 1.9 per cent under sugarcane, 1.1 per cent under maize and the rest under other miscellaneous crops. Food and non-food crops cover 71.8 per cent and 28.2 per cent of the irrigated area respectively.

17.20 From the agricultural point of view, the seasons are (i) the kharif or monsoon and (ii) the rabi or cold weather. Wherever irrigation facilities exist, perennial and eight month crops are cultivated. The sowing and harvesting seasons of the principal crops in the two States are shown in Table 17.6.

REGIONAL ECONOMY

Population

17.21 On the basis of the 1971 census* and the percentage of the area

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*Census Paper I of 1971 (Supplementary), Registrar-General (India).

Table 17.6
Sowing and Harvesting Seasons

Name of crop	Period of	
	Sowing	Harvesting
1	2	3
Rajasthan		
Wheat	October-December	March-May
Maize	June-July	September-November
Barley	October-December	March-April
Gram	September-November	February-April
Sugarcane	June-May	November-February
Cotton	May-July	October-December
Rice	July-August	October-December
Bajra	June-July	September-November
Gujarat		
Rice (Autumn)	June-July	October-November
Wheat	November	February
Gram	October-November	November-March
Kharif jowar	June-August	October-February
Rabi jowar	September-October	December-February
Bajra	June-July	September-October
Maize	June-July	September-October
Sugarcane	October-June	December-March
Cotton	July	December-April

Source: Indian Crop Calendar, Ministry of Food, Agriculture, C.D. and Co-operation (1967).

of each district within the basin to the district as a whole, the total population in the basin is about 21.82 millions. The State-wise distribution is given in Table 17.7.

Table 17.7
Population in the Basins

State	Population (Millions)
Rajasthan	8.64
Gujarat	13.16
Diu	0.02
Total	21.82

There are six cities in the basin which have a population of more than one lakh. They are Bhavnagar, Jamnagar and Rajkot in Gujarat and Ajmer, Bikaner and Jodhpur in Rajasthan. The average density of population in the basin is 68 persons per sq. km. The density varies from region to region within the basin. The most densely populated district of Ahmedabad in Gujarat has 334 persons per sq. km. while the district of Jaisalmer in Rajasthan has only 4 persons per sq. km. 74.5% of the population in the basin live in rural areas and the balance 25.5% in urban areas. The working force constitutes about 31.9% of the population. Nearly 53.2% of the working force is engaged as cultivators, 15.6% as agricultural labourers and the balance of 31.2% is employed on other activities.

Forests & Agriculture

17.22 Forests and agriculture are the mainstay of the people. Nearly 2.5% of the total area of the basin is covered by forests. The forests are largely confined to the southern portion of the basin in the districts of Gujarat. The forests are mainly of the dry tropical variety. The area annually cropped in the basin is about 14.8 million hectares. Agriculture is generally rain-fed with relatively low yields except for about 1.22 million hectares of irrigated area, which mainly grows wheat, cotton and oil seeds.

Power

17.23 The Central Water & Power Commission has conducted surveys to assess the hydroelectric potential of the country. The hydroelectric potential of this basin is practically nil. At present, the demand for electrification of towns and industries etc. is mainly met by means of diesel and thermal power plants. There are eight thermal stations in the basin, details of which are given below:

Table 17.8
Thermal Power Stations

Station	Installed capacity MW
Jodhpur	7.8
Jaipur	13.4
Jodhpur extension	3.0
Kandla	10.0
Sikka	16.0
Porbandar	15.0

Table 17.8—Contd.

Bhavnagar		11.6
Shahpur		16.0
	Total	92.8

Mineral Wealth

17.24 The principal minerals found in the basin are:*

Iron Ore: In the Jaipur, Udaipur, Jamnagar and Junagadh districts.

Manganese Ore: In the Udaipur district.

Copper: In the Jhunjhunu district.

Lead and Zinc (with Cadmium and Silver): In the Udaipur district.

Bauxite: In the Jamnagar district.

Gypsum: In the Bikaner, Jaisalmer, Jodhpur, Nagaur, Kutch, Jamnagar and Bhavnagar districts.

Mica: In the Jaipur, Ajmer and Udaipur districts.

Limestone: In the Sikar, Nagaur, Pali, Jaipur, Sirohi, Jamnagar and Junagadh districts.

Fluoride: In the Sikar district.

Feldspar: In the Ajmer, Jodhpur and Sirohi districts.

Talc: In the Jaipur, Udaipur and Sirohi districts.

Glass-sand and Quartz: In the Bikaner, Ajmer, Jaipur and Sirohi districts.

Asbestos: In the Ajmer, Udaipur and Jodhpur districts.

Bentonite: In the Barmer and Bikaner districts.

Calcite: In the Sikar, Jhunjhunu, Sirohi, Jaipur and Jamnagar districts.

Clays: In the Ajmer, Udaipur, Bikaner, Jodhpur districts.

Emerald: In the Ajmer and Udaipur districts.

Graphite: In the Ajmer and Banswara districts.

Lignite: In the Bikaner, Kutch and Jamnagar districts.

Industries

17.25 The important industries in the basin are as under:

Textile Cotton: In Ajmer, Beawar, Pali, Morvi, Porbandar and Bhavnagar.

Textile Woollen: In Ajmer and Jamnagar.

Silk and other fabrics: In Ganganagar, Jamnagar and Bhavnagar.

Sugar: In Ganganagar and Ajmer.

Tobacco products: In Beawar and Mehsana.

Vegetable oils: In Morvi, Porbandar and Palitana.

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*Techno-Economic Survey of Gujarat and Rajasthan, NCAER.

Plastic and allied products: In Ajmer and Jamnagar.
Rubber and rubber goods: In Bhavnagar.
Glass and Ceramics: In Jamnagar and Bhavnagar.
Cement: In Jamnagar, Dwarka, Porbandar and Bhavnagar.
Matches: In Marwar and Bhavnagar.
Automobile parts: In Bhavnagar.
Ship-building and dockyards: In Kandla.
Bicycles: In Jodhpur.
Machine tools: In Morvi and Viramgam.
Electrical equipment and appliances: In Bhavnagar.
Agricultural equipment: In Ajmer, Mehsana and Jamnagar.
Machinery: In Rajkot.
Machine parts: In Morvi, Rajkot and Bhavnagar.
Chemicals (Acids and Caustics): In Jodhpur, Kuda, Morvi, Porbandar and Bhavnagar.
Inks, Paints and Varnishes: In Jodhpur, Kura, Jamnagar, Porbandar, Rajkot and Bhavnagar.
Fertilizers: In Pali.
Soaps: In Jamnagar, Porbandar and Bhavnagar.
Drugs and Pharmaceuticals: In Bikaner, Ajmer and Bhavnagar.

Communications

17.26 The basin is served by the network of the Northern and Western Railways. The entire system is on metre-gauge. The basin is also served by a network of roadways. The National Highway connecting Delhi-Jaipur-Ahmedabad-Rajkot-Porbandar passes through the basin. There are other State Highways and district roads connecting important places in the basin. In the southern part of the basin lying in Rajasthan, the communication facilities have not been developed. None of the rivers in the basin is navigable.

The economy of the basin at present largely depends on agriculture, which, in view of the limited and uneven incidence of the rainfall, provides a low level of subsistence except in parts of the basin where facilities of irrigation have been provided and where major industries have developed. There is a keen demand for the development of the available water resources in the basin.

WATER RESOURCES

Surface Waters

17.27 In 1949 when the basin-wise assessment of the water resources of the country was made on the basis of Khosla's formula the annual runoff of the basin of the Luni and other rivers of Saurashtra and Kutch was estimated to be 8,807 m. cu. m.*

In 1960, the Central Water and Power Commission while conducting irrigation potential studies, assessed the total annual run-off of the basin as 12,278 m. cu. m.† based on the available observed data and Strange's coefficients of rainfall run-off.

Systematic gauge and discharge observations have been started on the rivers of Saurashtra and Kutch by the Gujarat State recently. The observations are being conducted by the Gujarat State Government at 25 Stations as detailed below:

Table 17.9

Gauge and Discharge Sites

Station 1	River 2
Roho	Banas
Bhakudar	Sipu
Dantiwada	Banas
Deesa	Banas
Malpur	Balaram
Matarwadi	Saraswati
Anawada	Saraswati
Umarkot	Gorad Vehela
Jethi	Gorad Vehela
Juni Sarotri	Mota Rabaria Vehla
Runi	Rel
Khodiar	Shetrunji
Sarambhada	Shetrunji
Ghatwad	Shinghoda
Dhateshwar	Dhatarwadi
Bhadar Dam	Bhadar
Aji II Dam	Aji
Fulzar II Dam	Fulzar
Jodhpur	Machhu
Surendranagar	Bhogavo
Birapur	Sukhabhadar
Machhundri	Machhundri
Raval	Raval
Raidi	Raidi
Barvala	Utaoli

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*An appraisal of water resources by Dr. A. N. Khosla, UNESCO.

†Report of technological possibilities of irrigation projects in India, Central Water and Power Commission (Unpublished).

Information regarding hydrological observations on the Luni and other streams in Rajasthan area is not available.

17.28 The Central Water and Power Commission, under the programme of establishing and maintaining Centrally sponsored hydrological stations in the country, has proposed establishment of the following five gauge and discharge sites on the Luni and other rivers:

Table 17.10

Proposed Gauge and Discharge Sites

Name of the River	Location of gauge and discharge site
Luni	Below its confluence with Sagi river
Banas	At Kamlapur
Machhu	16 km. above its outfall
Shetrunji	Near Shetrunji
Bhadhar	Near Gonod

The Commission has also recommended that the existing gauge and discharge site on the Luni near Jaswant Sagar may be maintained by the Rajasthan Government.

Ground Water

17.29 Systematic investigations and studies of the ground water potential of the basin have not been made so far. Only in some parts of the basin have some investigations and studies been done recently.*

That part of the Ajmer district lying in the basin is underlain by precambrian rocks. Only in parts of Sabarmati and Saraswati river valleys does ground water occur in alluvium and blown sands. Irrigation possibilities from tubewells exist in the alluvial tracts of these basins and in the internally drained Pushkar and Dudha Pushkar valleys.

In the Pali district investigations have shown that tubewells of shallow depth may be feasible in some fresh water tracts to the south of Sojet Road Station and close to the Mitri river near Falna. In view of the general salinity, tubewell irrigation will probably be feasible in localised areas. In that part of the Nagaur district lying in the basin tubewell irrigation is feasible.

Jodhpur district constitutes a saline tract and is generally not suitable for irrigation by ground water except in a few localities. Greater part of the Barmer district is also not suitable for tubewell irrigation. In the Jalore district prospective areas for ground water development exist in the Sukri river catchment. The extreme western part of this district adjoins the artesian basin of Cambay. In favourable localities deep tubewells may give rise to flowing conditions but the ground water quality may deteriorate markedly towards the Rann of Kutch.

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*Ground Water Resources of India, Status and Surveys, Prospects and Perspectives, Geological Survey of India (August, 1970).

The Banas river basin is mostly covered by alluvium. Ground water occurs in the alluvium and is suitable for irrigation by shallow tubewells.

In the Mehsana district, the ground water occurs under water-table and confined conditions. The western half of the district forms a part of extensive artesian basin extending from Banaskantha in the north towards the Kaira district in the south. The quality of ground water deteriorates progressively from east to west. Further development of ground water for irrigation is feasible by tapping deeper aquifers (130 to 300 m.).

In the coastal tracts of Saurashtra, the development of ground water for irrigation will have to depend on miliolite limestone. It is possible that along some of the major streams, the thickness of the fresh water zone may be sufficient to sustain tubewells. However, such areas may be localised to small pockets.

Kutch and other adjoining areas are underlain by the Deccan trap and Sedimentary rocks.

The Deccan trap has poor water bearing formations. Among the sedimentary rocks, the most productive aquifers are in the Bhuj series, which comprise soft and medium to coarse grained sandstones.

Further systematic exploratory work is necessary in the basin to make a scientific qualitative and quantitative assessment of the ground water resources. When such an assessment is made, it will help to frame a rational plan of development for various needs.

EXISTING DEVELOPMENT

17.30 The First Indian Irrigation Commission had not recommended any specific projects by name, to be taken up for construction in the basin.* Prior to 1947 there was only one project, namely the Vijayasagar Project in Gujarat State.

During the Plan periods, several projects have been taken up for construction in the basin. The more important of these are described in the following paragraphs:

Jawai Project

17.31 The project consists of a dam, 871 m. long and 34 m. high across the river Jawai, a tributary of the Luni, in the Pali district of

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*Report of the Indian Irrigation Commission (1901-03).

Rajasthan. It was started in 1948 and was completed in 1959 at a cost of Rs. 25.00 million. The project provides irrigation to 7,690 hectares.

Machhu Project (Stage-I)

17.32 The project has been constructed across the river Machhu at a cost of Rs. 15.83 million for irrigating 6,760 hectares in the Rajkot district. It was started in 1952 and completed in 1961.

Shetrunji (Palitana) Project

17.33 The project comprises a composite dam 3,896 m. long, 38.1 m. high, across the river Shetrunji, 10.4 km. from Palitana town in the Bhavnagar district of Gujarat for irrigating an area of 34,804 hectares. It was started in 1955 and completed in 1965 at a cost of Rs. 69.60 million.

Banas (Dantiwada) Project

17.34 The project consists of a composite dam 4,815 m. long, 61 m. high across the river Banas near the village of Dantiwada in the Banaskantha district of Gujarat, costing Rs. 108.79 million. It will irrigate an area of 44,517 hectares. The project was started in 1958 and completed in 1969.

Shetrunji (Khodiar) Project

17.35 Constructed across the river Shetrunji, the project is intended to provide irrigation to 7,689 hectares in the Amreli district of Gujarat. It was completed in 1969 at a cost of Rs. 16.32 million.

Bhadar Project

17.36 Located in the Bhadar sub-basin, the project provides irrigation to 18,061 hectares in the Rajkot district. The total expenditure incurred on the project is Rs. 42.80 million.

Rudramata Project

17.37 The project provides for an earth dam across the river Pus, 14 km. north of Bhuj town and a canal system on either side to irrigate 7,200 hectares. The total cost of the project is Rs. 10.60 million. Started in 1959, the project is likely to be completed during the Fourth Plan.

Machhu Project (Stage-II)

17.38 The project envisages an earth dam 3,818 m. long with a masonry spillway 206 m. long in the gorge of the river Machhu near the village of Jodhpur in the Rajkot district and a canal on the left bank for irrigating 7,689 hectares. The project taken up in 1961 at a cost of Rs. 21.39 million, is likely to be completed during the Fourth Plan.

Saraswati Project

17.39 The project comprises a 319 m. long barrage-cum-bridge across the river Saraswati near Patna town in the Mehsana district and a canal taking off on the left bank for irrigating 8,742 hectares. Costing Rs. 21.20 million, the project was taken up for construction in 1965 and is likely to be completed during the Fourth Plan.

17.40 Some particulars of the major and medium projects under operation and construction in the basin are given in Appendices 17.1 and 17.2.

17.41 Besides major and medium projects, a number of minor schemes comprising tanks and wells irrigate a very large area in the basin. The details of the area irrigated by various sources like canals, tanks, wells etc. during the year 1967–68, in the basin are given below:

Table 17.11

Area Irrigated—Sourcewise

Sl. No.	Source of irrigation	Area irrigated ('000 hectares)		
		Rajasthan	Gujarat	Total
1	2	3	4	5
1.	Canals	97.2	90.7	187.9
2.	Tanks	42.7	9.6	52.3
3.	Tubewells	1.1	33.0	34.1
4.	Wells	270.2	544.9	815.1
5.	Other sources	1.7	1.9	3.6
	Total	412.9	680.1	1,093.0

By the end of 1968–69, the area under minor schemes increased by about 72,970 hectares.

17.42 In the absence of data regarding the annual diversions and utilisations by the major and medium projects under operation and construction as in 1968–69 in the basin, the utilisation on their full development has been approximately estimated to be of the order of 2,107 m. cu. m. by the Commission.

No statistics of the large number of minor schemes comprising tanks, wells and other diversions are available. Based on the area irrigated from these sources and on rough duties, the approximate estimate of the quantity of water diverted for irrigation by these works has been made. The approximate annual diversion by the minor schemes under operation and construction in 1968–69 may be of the order of 8,941 m. cu. m.

Reservoir Losses

17.43 On the basis of assumptions detailed in para 1.33 the reservoir losses from the various schemes in the basin will be as under:

(i) Major and Medium Schemes	399 m. cu. m.
(ii) Minor Schemes (tanks)	754 m. cu.m.
Total	1,154 m. cu. m.

17.44 Thus, the total annual utilisation, including reservoir losses, by the major, medium and minor projects under operation and construction in 1968–69 in the basin would be of the order of 12,201 m. cu. m. of which 3,812 m. cu. m. is from surface waters and 8,389 m. cu. m. from ground waters.

17.45 A very large area lying in the western extremity of the basin along the Pakistan border falls under the command of the Rajasthan Canal Project, which is under construction in Rajasthan. The Rajasthan Canal takes off from the Harike Barrage across the river Sutlej in Punjab. It has a total length of 685.55 km. of which the first 215.65 km. lie in Punjab. The project is intended to utilise part of the surplus Ravi-Beas waters allocated to India under the Indus Water Treaty (1960).

17.46 There are a number of major industries located in the basin, especially around Jamnagar and Bhavnagar. The data on the present industrial water needs are not readily available. In future, such needs are expected to grow. The problem of water pollution in the basin due to discharges of industrial wastes has not been reported so far. However, the problem may arise in future and will have to be guarded against.

FUTURE DEVELOPMENT

17.47 One major project, namely the Sipu Reservoir Project, is proposed to be taken up for construction in the Fourth Plan period, in Gujarat State. The Project provides for a dam across the Sipu river, a tributary of the Banas, in the Banaskantha district. It will provide irrigation to 25,300 hectares and cost Rs. 59.47 million. The Sipu Reservoir Project will utilise about 234 m. cu. m. of water, including reservoir losses. Appendix 17.3 shows the salient features of the above project. There are no new projects to be taken up in the basin in Rajasthan State during the Fourth Plan.

By the end of the Fourth Plan, the area under minor schemes is expected to increase by about 0.50 million hectares requiring nearly 4,928 m. cu. m. of water, including reservoir losses.

Thus, the additional utilisation by the Fourth Plan major, medium and minor projects would be of the order of 5,162 m. cu. m. benefiting an area of about 0.52 million hectares.

On full development of Fourth Plan projects, a total quantity of 17,363 m. cu. m. of water (4,711 m. cu. m. of surface water and 12,652 m. cu. m. of ground water) would have been used for irrigating a total area of about 1.73 million hectares.

The concerned State Governments have not indicated the new projects which are proposed to be taken up by them, in the future, in the basin. If the Navagam High Level Canal and the Kadana High Level Canal materialise, a very large area in the basin, lying in the Gujarat State, will come under the command of these two high level canals and will be fed by the Narmada and Mahi waters.

FLOODS, WATERLOGGING AND DRAINAGE

17.48 The Luni and other rivers of Saurashtra and Kutch area do not present any serious flood problem either in Rajasthan or in Gujarat. No flood control works have been undertaken by those States.

17.49 Waterlogging in the areas under the irrigated commands in the basin has not been reported so far as there is very little perennial irrigation. Drainage and salinity control measures are badly needed in the Rann of Kutch.

SOIL CONSERVATION

17.50 The basin has hardly 2.33 per cent of its area under forests. This percentage is very low when compared with the all-India average and the standard laid down in the 1952 Forest Policy Resolution. Afforestation is called for in the basin.

The foremost soil problem in the Ajmer-Merwara area of Rajasthan is the loss due to the erosion of top soils resulting from overgrazing and the indiscriminate felling of trees. For protecting the soil, one of the most urgently needed items of work is the planting of suitable species of trees and shrubs on the steep slopes and on the summits of the hills. The village common forests have been ruined by the unrestricted grazing of cattle, sheep and goats throughout the year and the indiscriminate cutting down of the trees and shrubs by the villagers. Reclamation projects such as those of Barakhan near Todgarh and Lohagol near Ajmer, demonstrate the possibility of improving the village forests by closing them to grazing. Afforestation of the hills and hill slopes, apart from increasing the wealth of the State, will have an indirect effect on wind erosion. The plantations at Pushkar illustrate very well how wind erosion can be controlled by the planting of trees.

17.51 Intensive wind erosion occurs in the desert areas of the basin extending over north Gujarat, south-west Punjab and west and north-west Rajasthan. The whole area is a sandy plain but the soil improves in fertility from north-west to north-east. On the rocky hills and plateaus the soil is shallow, eroded and devoid of vegetation as the top soil has been blown or washed away. In the Rann of Kutch there are extensive sand, silt and mud flats. The rainfall is erratic, the wind velocity is high and water is scarce. Contour bunding is necessary to hold rain water and conserve moisture.

17.52 For the conservation of river supplies and especially of the storage capacities created in the reservoirs, it is important that soil conservation measures are undertaken in the basin both in the uncultivated and cultivated areas.

17.53 The Dantiwada project in the Banas basin has been included in the Centrally sponsored programme of soil conservation in the catchments of major river valley projects. The scheme is being executed by three different departments viz. the Forest Department, the Agriculture Department and the Public Works Department. The Forest Department attends to the soil conservation works in the forest areas, panchayat areas and waste lands. The Agriculture Department limits its activities to the private agricultural lands, while the Public Works Department looks after the establishment of silt and discharge measurement sites. The progress made in respect of the Dantiwada project is shown in Table 17.12.

Table 17.12

Soil Conservation Works in Dantiwada Catchment

Sl. No. 1	Year 2	Works carried 3	Expenditure incurred 4
1.	1962-63	Establishment of 1 forest nursery and soil survey in 130 sq. km.	Rs. 12,935.00
2.	1963-64	Afforestation in 300 hectares, soil conservation in cultivated fields in 522 hectares, soil survey in 544 sq. km. and establishment of 2 silt and discharge measurement sites.	Rs. 236,118.00
3.	1964-65	Afforestation in 621 hectares, soil conservation in cultivated fields in 1,014 hectares and establishment of 1 and maintenance of 2 silt and discharge measurement sites.	Rs. 385,015.00
4.	1965-66	Afforestation in 641 hectares, soil conservation in cultivated fields in 1,198 hectares and maintenance of 3 silt and discharge measurement sites.	Rs. 411,283.36
5.	1966-67	Afforestation in 812 hectares, soil conservation in cultivated fields in 638 hectares and purchase of material for 2 silt observation posts.	Rs. 412,569.00
6.	1967-68	Afforestation in 190 hectares, pasture development in 20 hectares, soil conservation in cultivated fields in 598 hectares and maintenance of silt and discharge measurement sites.	Rs. 319,292.00
7.	1968-69	Afforestation in 300 hectares, pasture development in 150 hectares. For grafting 1,726 grafts, soil conservation in cultivated fields in 617 hectares and maintenance of 8 silt and discharge measurement sites and 4 raingauge stations.	Rs. 462,403.00
		Total	Rs. 2,239,615.36

The year-wise programme and outlay envisaged under the Fourth Five Year Plan for soil conservation in the catchment area of Dantiwada Project is given below:*

Table 17.13

Fourth Plan Proposals for Dantiwada

Sl. No.	Year	Area in hectares proposed to be treated	Financial target
1.	1969-70	3,560	Rs. 688,210.00
2.	1970-71	3,950	Rs. 1,097,220.00
3.	1971-72	3,450	Rs. 1,029,270.00
4.	1972-73	3,750	Rs. 1,035,320.00
5.	1973-74	3,350	Rs. 939,370.00
	Total	18,060	Rs. 4,789,390.00

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*Replies of Gujarat to the Questionnaire issued by the Irrigation Commission.

The capacity survey of the Dantiwada reservoir has not been undertaken so far. Under the Centrally sponsored programme of soil conservation, the gauging for discharge and silt upstream of the reservoir has been started from 1963. The data collected is yet to be analysed.

GENERAL

17.54 The number and distribution of rain-gauge stations should be reviewed and new stations to fill any gaps should be established. It is also important that the daily rainfall data for all these stations should be published on a monthly basis.

17.55 A network of evaporation measuring stations in the basin, particularly at the sites of the existing and proposed reservoirs needs to be established.

17.56 Gauge and discharge observations should be made on the various river systems in the basin. Many of the rivers in the basin are not being gauged at present. The observations should be continued in a scientific way on a permanent basis to obtain data essential not only for the preparation of the individual projects but also for the regulation of available river waters.

17.57 Systematic and scientific exploratory work is needed for a quantitative and qualitative assessment of the ground water resources in the basin so that these can be exploited in a rational way either independently or in conjunction with surface waters.

17.58 There is need for carrying out soil conservation measures in the basin to conserve the storage capacities of existing and proposed reservoirs.

17.59 Systematic data in respect of the sediment carried by the rivers needs to be collected.

SALIENT FEATURES OF THE INDUS BASIN*

(i) Source: Behind the great mountain wall of the Himalaya between the Kailash and Ladakh ranges, around Manasarowar (Latitude 30°N, Longitude 81°E).

(ii) Length of the Indus in Jammu & Kashmir	1,114 km.	692 miles

	Sq. km.	Sq. miles
(iii) Drainage area		
Jammu & Kashmir	193,762	74,812
Himachal Pradesh	51,356	19,829
Punjab	50,304	19,422
Haryana	9,939	3,837
Rajasthan	15,814	6,106
Chandigarh	114	44
Total	321,289	124,050

(iv) Population (1971 Census)	24.63 millions	
(v) Density of Population	77 per sq. km.	199 per sq. mile

	Cumecs	Cusecs
(vi) Maximum discharge		
The Jhelum near Indo-Pakistan border	29,600	1,045,315
The Chenab ,, ,, ,,	24,700	872,273
The Ravi ,, ,, ,,	15,400	543,846
The Beas at Mandi Plain	9,800	346,084
The Sutlej near Indo-Pakistan border	12,000	423,776
(vii) Minimum discharge		
The Jhelum near Indo-Pakistan border	112	3,955
The Chenab ,, ,, ,,	102	3,602
The Ravi ,, ,, ,,	34	1,201
The Beas at Mandi Plain	60	2,119
The Sutlej near Indo-Pakistan border	78	2,755

(viii) Average annual runoff based on Khosla's formula	76,907 m. cu. m.	62.35 MAF

	Thousand hectares	Thousand acres
(ix) Culturable area (1967-68)	9,638	23,816
(x) Net area sown (1967-68)	6,969	17,221
(xi) Gross area sown (1967-68)	9,322	23,036
(xii) Net area irrigated (1967-68)	3,302	8,160
(xiii) Gross area irrigated (1967-68)	4,742	11,718
(xiv) Area irrigated after completion and full development of Fourth Plan Projects	7,174	17,728
(xv) Probable additional irrigation by future projects	N.A.	

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*All statistics pertain to the part of the basin lying in Indian territory only.

(xvi) Water utilisation including reservoir losses		m. cu. m.	MAF
(a) On completion & full development of major, medium & minor projects under operation and construction in 1968-69	Surface water	46,048	37.33
	Ground water	8,515	6.90
	Total	54,563	44.23
(b) On completion & full development of Fourth Plan Projects	Surface water	46,638	37.81
	Ground water	13,650	11.07
	Total	60,288	48.88

CHAPTER XVIII

THE INDUS BASIN

The Indus Basin extends over an area of about 1,165,500 sq. km. In Indian territory it lies between east longitudes 72°33′ to 79°50′ and north latitudes 28°52′ to 37°20′. The basin covers areas in China (Tibet), India, Afghanistan and Pakistan. In India, the basin lies in the States of Jammu & Kashmir, Himachal Pradesh, Punjab and parts of Haryana and Rajasthan, besides the Union Territory of Chandigarh. The State-wise distribution of the drainage basin within the country is given below:

Table 18.1

Indus Basin—State-wise drainage areas

State	*Drainage area in sq. km.*
Jammu & Kashmir	193,762
Himachal Pradesh	51,356
Punjab	50,304
Haryana	9,939
Rajasthan	15,814
Chandigarh	114
Total	321,289

18.2 The Indus Basin is bounded on the east by the Himalayas, on the north by the Karakoram and Haramosh ranges, on the west by the Sulaiman and Kirthar ranges and on the south by the Arabian Sea. The basin in Indian territory has a maximum east-west length of about 855 km. along 75° east longitude and a maximum north-south width of about 560 km. along 34°25′ north latitude. The basin has a double fan or palm shape.

The upper portion of the basin lying in Tibet (China), Jammu & Kashmir, Himachal Pradesh and part of Pakistan comprises mostly mountain ranges and narrow valleys. In Punjab, Haryana and Rajasthan in India and West Punjab and Sind in Pakistan, the basin is one flat vast stretch of what was once desert and waste land, but which is now the renowned and fertile granary of both countries. Down south, in Sind, the basin includes some delta areas.

THE RIVER SYSTEM

18.3 The Indus rises in Tibet (32°N and 81°E) behind the great mountain wall of the Himalaya, at an elevation of 5,182 m. Issuing from the lofty mountains around Manasarowar, it flows northwest under the name of Singge-Khabab until it is joined, about 257 km. from its source, by the Ghat. A short distance lower down, it enters the south-eastern corner of Kashmir at an elevation of 4,206 m. and flows over a long flat of alluvium. It skirts Leh at 3,200 m. and is joined by the Zaskar river near the crossing of the great trade route into Central Asia via the Karakoram pass. Still flowing north, but bearing west, the Indus passes near Skardu and reaches the Haramosh mountain (7,407 m.). Here it takes a turn southwards at an acute angle and passing beneath the Hattu Pir enters Kohistan. After flowing through the wilds of Kohistan and at about 1,448 km. from its source, the Indus is joined opposite Attock (Pakistan) by the Kabul river from Afghanistan. At this point the river has fallen to an elevation of about 610 m. After leaving Attock, the Indus flows southwards, parallel to the Sulaiman range. Just above Mithankot, about 805 km. from the sea, and at an elevation of 79 m., the Indus receives, from the Panjnad, the accumulated waters of the five eastern tributaries. The river finally empties itself through mouths into the Arabian Sea, near Karachi. The total length of the Indus, from its source to the sea, is 2,880 km. out of which about 1,114 km. lies in India. Its principal tributaries, the Kabul and the Swat on its right and the Jhelum, the Chenab, the Ravi, the Beas and the Sutlej, on its left, have a total length of 5,600 km. Its catchment area up to the Indo-Pakistan border is about 168,335 sq. km.

18.4 The Jhelum is known in Kashmir as the Veth. It has its source in Verinag, a spring at the bottom of a high scarp of a mountain spur, at the upper end of the Kashmir valley. The river has several tributaries in the valley; many of these come from the everlasting snows of the Liddar valley. Below Srinagar, it receives the Sind and beyond the Wular Lake, which is in fact a delta of the river, the Pohru stream from the Lolab valley. Below Baramula, the Jhelum leaves the fertile banks of the valley and rushes headlong down a deep gorge between lofty mountains. At Muzaffarabad, the Kishanganga joins the Jhelum from the right. Lower down, the river skirts the outlying spurs of the Salt Range and finally debouches into the plains near the city of Jhelum in Pakistan. About 322 km. lower down, it joins the Chenab at Trimmu. Up to the Indo-Pakistan border, its length is about 402 km. and the corresponding catchment area is 34,775 sq. km.

18.5 The Chenab rises in two streams—the Chandra and the Bhaga in the Himalayan canton of Lahul in the Himachal Pradesh. The united stream, known as the Chandrabhaga or Chenab, flows through the Pangi valley and enters Kashmir at an elevation of 1,828 m. It flows for 290 km. between steep cliffs and then for 40 km. through the lower hills to Akhnur where it enters Pakistan near the Marala weir, below the junction of the Tawi. In Pakistan, the Chenab flows for more than 644 km. to Panjnad, where it joins the Sutlej, having received the waters of the Jhelum about halfway at Trimmu and of the Ravi a little lower down. From the confluence of rivers, the Chandra and the Bhaga, to the Indo-Pakistan border the river has a length of 378 km. Its total catchment area up to the Indo-Pakistan border is 26,155 sq. km.

18.6 Of all the Punjab catchments the Ravi catchment of only about 14,442 sq. km. is the smallest. The river rises near the Rohtang Pass in the Kangra district and drains the southern slopes of the Dhauladhar. After crossing the Siwaliks, it enters the Punjab plains at Madhopur. From its source to the Indo-Pakistan border, the river has a length of about 370 km. The river passes into Pakistan about 26 km. below Amritsar.

18.7 The Beas rises on the southern face of the Rohtang Pass, 4,062 m. above sea level. Fairly steep in its upper portion (24 m. per km.), it meanders lower down in a westerly course through hilly country. On meeting the Siwalik hills in Hoshiarpur, the river sweeps sharply northward, then bending round the base of the hills, it takes a southerly direction. In this portion of its course, through the uplands of the Punjab plains, a strip of low alluvial soils fringes its banks, subject in flood-time to inundation from the central streams. Lower down, the river shifts from year to year through the alluvial valley and finally joins the Sutlej at Harike after a total course of 460 km., wholly in India. It drains an area of 20,303 sq. km.

18.8 The Sutlej rises in the distant highlands of Tibet at an elevation of about 4,570 m. from the Manasarowar lake. It has a very long course through the mountain ranges, rising to 6,100 m. on either side. It passes through Himachal Pradesh and then enters the Punjab in the Hoshiarpur district. The Sutlej emerges from the Siwalik hills at the Bhakra gorge and flows as a narrow deep stream with low hills on either side for about 16 km. before it widens into an alluvial river. It receives the Beas at Harike above Ferozepur, before joining the Chenab at Madwala in Pakistan. The slope of the Sutlej from its source to Bilaspur is steep and fairly uniform, but lower down, it gradually flattens to 1:5,000 or even less in the plains below Rupar. From Manasarowar lake to the Indo-Pakistan border, the river has a length of 1,078 km. and a catchment area, excluding that of the Beas, of 204,058 sq. km. (including the head reach in Tibet).

18.9 The river Ghaggar has its source near Dagshai a small hill station at an elevation of 1,927 m. (77°3′ east longitude, 30°50′ north latitude) in the Simla district of Himachal Pradesh. The river flows in a generally south-westerly direction practically throughout its length. It enters the State of Haryana near Kalka about 10 km. from its source. Continuing to flow in the same direction, the river criss-crosses the boundary line between Punjab and Haryana at a number of places. The Patielawali Nallah joins it at two different places on its right bank before it receives, through the Saraswati, the combined waters of its three important left bank tributaries viz. the Tangri, the Markanda and the Saraswati, near village Shatrana, about 148 km. from its source. From here on, the direction of flow of the river is more westerly than southerly. From about 8 km. down stream of this confluence the river crosses the Bhakra Main Line Canal and about 28 km. further lower down, the river crosses the Ghaggar Branch of the Bhakra system. Continuing to flow for about 107 km. more in a generally south-westerly direction, the river is tapped at Ottu headworks (weir) where two canals, one Northern and the other Southern take off for irrigating the nearby areas. The canals go a little beyond Hanumangarh town in Rajasthan. Thereafter, the river disappears in the sand dunes of the Rajasthan desert. The river has a total length of about 291 km. and its drainage area, though difficult to assess precisely, can roughly be placed around 1,309 sq. km. up to the Ottu Weir.

CLIMATE

Seasons

18.10 Climatically the year in the Indus basin can be divided into three major seasons.

(i) The hot weather season (April to June)
(ii) The rainy season (July to September)
(iii) The cold weather season (October to March)

The climate of the region varies from arctic cold in Ladakh and the perpetually snow clad peaks in parts of Himachal Pradesh to the tropical heat of the sub-montane and plain tracts of Punjab and Rajasthan.

In summer due to the increase in temperature, the atmospheric pressure falls over the heated land. The humidity also drops. The day temperature increases considerably in association with the heat waves which generally develop during the period over North India. The temperature rises as high as 47.8°C in parts of Rajasthan. Occasionally dust storms bring about a sudden fall in temperature and sometimes these storms are followed by a shower of rain which results in lowering the temperature slightly.

18.11 The rainy season commences in the month of July and lasts till September. The major part of the precipitation occurs in this period. The monsoon showers bring relief after the prolonged heat of the summer season. These rains are essential for the prosperity of the kharif crops and the sowing of the rabi crops.

The cold weather starts in the month of October. November is slightly cooler. December and January are markedly cold and the temperature sometimes falls below freezing point in parts of Jammu & Kashmir, Himachal Pradesh and even Rajasthan. There are some winter rains during these months. Though the rainfall is not considerable, except in the hills which experience snow, it is crucial for the rabi crops.

Rainfall

18.12 There are 239 reporting rain-gauge stations in the basin. The density works out to one station for every 1,460 sq. km. The number of gauges being insufficient, the establishment of more rain-gauges to obtain a balanced distribution over the entire basin is suggested. In selecting the locations for new rain-gauges, care should be taken to see that all areas in the basin are suitably represented.

18.13 The rainfall data of all existing rain-gauge stations are being observed and printed by the Rainfall Registration Authorities of the concerned States. This data appears in the annual volumes of the 'Daily Rainfall of India' compiled and issued by the India Meteorological Department. Such volumes are available since 1891. The major part of the basin receives a rainfall of over 600 mm.

18.14 The south-west monsoon brings rains in the summer months while the winter rains are caused by the storms in Jammu & Kashmir, which advance from Iran and Baluchistan. The annual rainfall in the plains of Punjab varies between 400 and 800 mm., while in the submontane districts, it is higher, and varies between 800 and 1,150 mm. In Rajasthan, parts of the Ganganagar and Bikaner districts receive hardly 190 and 230 mm. In Haryana the maximum rainfall of about 2,160 mm. occurs in the foothills. In Himachal Pradesh the rainfall varies from about 850 mm. in the Kinnaur district to 1,800 mm. in the Sirmur district. However, there are places in the Kangra district like Dharamsala and Palampur where the normal annual rainfall is as high as 3,200 mm. and 2,680 mm. respectively. 80 to 90% of the rainfall in the above States takes place during the months from July to September.

18.15 In the Jammu & Kashmir State, the rainfall pattern is somewhat different. The normal annual rainfall in the State varies from 1,900 mm. in Gulabgarh to 93 mm. in Leh (Ladakh). The south-west monsoon is the main source of precipitation in Jammu & Kashmir and Kistwar while winter precipitation is more important in Ladakh, Gilgit and the higher ranges. During the winter, the snowfall is heavy on the Pir Panjal range, the heaviest falls being in January and February. In the valley of Kashmir and the mountain ranges to the north and east, this is the chief precipitation of the year but it decreases rapidly eastwards to the Karakoram range where the winter snows occur much later and the maximum is received in April. The average snowfall in Srinagar is about 2,430 mm.

Temperature

18.16 During the winter season in January, the mean temperature over the catchment varies from 10.0°C or below in Jammu & Kashmir to 12.5°C in Punjab, Haryana and Himachal Pradesh and 12.5°C to 15.0°C in parts of Rajasthan.

During the summer season in April, the mean temperature in Jammu & Kashmir is lower than 25.0°C. In Punjab, Haryana, Himachal Pradesh and Rajasthan it varies from 25.0° to 27.5°C. In certain portions of Rajasthan it goes up to 30.0°C.

In the rainy season, in the month of July, the mean temperature varies from 30.0°C in Jammu & Kashmir, Himachal Pradesh, Haryana and Punjab to 32.5°C in parts of Rajasthan.

Towards the end of the monsoon season, in the month of October, the mean temperature in Jammu & Kashmir, Himachal Pradesh, Haryana and Punjab is less than 25.0°C. However, in certain parts of Punjab and Rajasthan it varies from 25.0°C to 27.5°C.

Annual normals of temperature and relative humidity at some selected places located within the basin are as shown in Table 18.2.

Table 18.2

Temperature and Humidity in the Basin

Station	Annual normals of temperature		Annual normals of relative humidity %
	Maximum (°C)	Minimum (°C)	
Ambala	31.2	17.3	62
Ludhiana	31.2	22.6	64

Evaporation

18.17 Practically no data on evaporation is available for the Indus basin. The India Meteorological Department has compiled the evaporation data in respect of 30 departmental observatories and 42 agro-meteorological observatories having data for more than five years scattered all over the country. Observations at all these places are taken with standard U.S. Evaporation Pan (Class A) covered with wire-mesh. For the departmental observatories, the data pertains to the period 1961 to 1968 and has been presented for 12 periods into which the calendar year is divided for agro-meteorological purposes. Within the Indus basin one departmental observatory is located at Bikaner and one Agro-meteorological observatory is located at Chandigarh.

SOILS

18.18 No systematic soil survey of the Indus basin has been carried out so far.

The basin covers fully ten districts of Jammu & Kashmir, six districts of Himachal Pradesh and ten districts of Punjab. Parts of Ladakh and Gilgit districts of Jammu & Kashmir; the Mahasu, Sirmur, Kinnaur and Simla districts of Himachal Pradesh; Sangrur district of Punjab, Hissar, Jind, Karnal and Ambala districts of Haryana and Ganganagar and Bikaner districts of Rajasthan also lie in the basin. The principal soil types found in the various districts in the basin are shown in Table 18.3.

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*Indian Crop Calendar, Ministry of Food, Agriculture, Community Development and Cooperation (1967).

Table 18.3

Soils of Indus Basin

Name of the State/ District	Predominant types of soils
1	2
Jammu and Kashmir	
Anantnag	Sub-montane
Srinagar	Sub-montane
Baramulla	Brown hill (on sand stones and shales)
Doda	Brown hill (on sand stones and shales) sub-montane
Udhampur	Sub-montane, mountain meadow
Jammu	Alluvial, brown hill (on sand stones and shales)
Kathua	Brown hill (on sand stones and shales), sub-montane
Poonch	Brown hill (on sand stones and shales), sub-montane
Ladakh	Glaciers and eternal snow mountain meadow brown hill (on sand stones and shales)
Gilgit	Brown hill, sub-montane and mountain meadow
(i) Agency	Sub-montane, mountain meadow, saline and alkaline, peaty and peaty saline, glaciers and eternal snow
(ii) Leased area	
Muzaffarabad	Brown hill and sub-montane
Mirpur	Alluvial and brown hill
Himachal Pradesh	
Mahasu	Brown hill (on sand stones and shales)
Kinnaur	Sub-montane
Mandi	Brown hill (on sand stones and shales)
Chamba	Sub-montane
Sirmur	Brown hill (on sand stones and shales), alluvial
Bilaspur	Brown hill (on sand stones and shales)
Simla	Brown hill (on sand stones and shales)
Kangra	Sub-montane (podsolic), brown hill (on sand stones & shales)
Kulu	Sub-montane (podsolic), brown hill (on sand stones & shales)
Lahaul & Spiti	Sub-montane (podsolic), glaciers and eternal snow

Table 18.3—contd.

1	2
Punjab	
Hoshiarpur	Alluvial, brown hill (on sand stones and shales)
Jullundur	Alluvial
Ludhiana	Alluvial, chestnut brown (alluvial)
Ferozepur	Chestnut brown (alluvial), desert
Amritsar	Alluvial, chestnut brown (alluvial)
Gurdaspur	Alluvial, brown hill (on sand stones and shales)
Kapurthala	Alluvial
Bhatinda	Chestnut brown (alluvial)
Sangrur	Chestnut brown (alluvial), alluvial
Patiala	Alluvial, chestnut brown (alluvial)
Ropar	Alluvial
Haryana	
Hissar	Chestnut brown (alluvial), desert
Jind	Chestnut brown (alluvial), alluvial
Karnal	Alluvial
Ambala	Alluvial
Rajasthan	
Ganganagar	Chestnut brown (alluvial), desert
Bikaner	Desert
Chandigarh	Alluvial

LAND USE AND AGRICULTURAL PRACTICES

18.19 State-wise land use details in the basin, as in 1967–68, the latest year for which the statistics are available, are given in Table 18.4.

The culturable area in the basin is about 4.9% of the total culturable area of the country. The total cropped area in the basin is about 5.7% of the cropped area in the country.

The area under irrigated crops is about 50.9% of the cropped area in the basin.

The general cropping pattern, State-wise, is described below:

Jammu & Kashmir

Of the gross irrigated area of about 315,600 hectares, 65.8% is under

Table 18.4

Land Use Details—Indus Basin

(Thousand hectares)

Item	Name of State/Union Territory						Total
	Punjab	Haryana	Himachal Pradesh	Rajasthan	Jammu & Kashmir	Chandigarh	
Gross area	5,030	994	5,136	1,581	19,376	114	32,189
Reporting area	4,989	983	4,296	1,575	2,418	N.A.	14,375
Area under forest	66	41	2,291	2	661	N.A.	3,061
Area net available for cultivation	634	114	198	68	548	N.A.	1,562
Culturable area	4,289	828	1,807	1,505	1,209	N.A.	9,638
Uncultivated culturable area	301	76	1,318	444	530	N.A.	2,669
Net area sown	3,988	752	489	1,061	679	N.A.	6,969
Area sown more than once	1,447	311	322	137	136	N.A.	2,353
Total cropped area	5,435	1,063	811	1,198	815	N.A.	9,322
Net area irrigated	2,331	252	84	352	284	N.A.	3,302
Gross area irrigated	3,460	403	143	421	316	N.A.	4,742
Percentage of net area sown to culturable area	54.3	30.4	4.7	23.4	23.5	N.A.	34.3
Percentage of net area irrigated to culturable area	93.0	90.8	27.1	70.5	56.2	N.A.	72.3
Percentage of net area irrigated to net area sown	58.4	33.5	17.2	33.2	41.8	N.A.	47.4

rice, 6.5% under wheat and 7.1% under maize. Fruits of various types are grown extensively. About 90.2% area is under food crops and 9.8% under non-food crops.

Himachal Pradesh

The gross irrigated area is about 142,600 hectares, of which 35.6% is under rice, 32.1% under wheat, 10.3% under maize and 4.1% under barley. Potatoes and apples are also important crops. Food and non-food crops account for 92.5% and 7.5% of the irrigated cropped area respectively.

Punjab

Of the gross irrigated area of nearly 3,459,600 hectares the food crops account for 69.6%, the balance of 30.4% being non-food crops. Of the gross irrigated area under food crops 36.4% is under wheat, 5.4% under gram, 7.4% under rice, 9.2% under maize and 3.3% under sugarcane. Cotton (11.6%) is the main non-food crop.

Rajasthan

Food crops constitute 57.6% of the gross irrigated area of about 421,200 hectares. Gram and wheat are the principal crops in this category covering 22.6% and 20.6% of the gross irrigated area respectively. Non-food crops account for 42.4% of the gross irrigated area. Cotton is the main crop covering 20.7% of the gross irrigated area.

Haryana

Out of the total irrigated area of 402,800 hectares 27.2% is under wheat, 16.4% under gram, 14.9% under cotton, 11.9% under paddy and 4.2% under sugarcane. Food and non-food crops cover about 71.6% and 28.4% of the irrigated area respectively.

Summing up, of the total irrigated area of 4,741,800 hectares in the basin, about 32.1% is under wheat, 12.0% under rice, 7.4% under gram, 7.6% under maize, 2.9% under sugarcane and 11.5% under cotton. The remaining area is under miscellaneous crops like barley, oil-seeds etc. Food and non-food crops cover 70.7% and 29.3% of the irrigated area respectively.

18.20 There are two main crop seasons, namely (i) the kharif and (ii) the rabi. The important kharif crops are rice and maize. The predominant rabi crops are wheat and gram. Wherever irrigation facilities exist, perennial and eight-month crops are also cultivated.

18.21 The sowing and harvesting seasons of the principal crops in the various States are shown in Table 18.5.*

Population

18.22 On the basis of the 1971 Census† and the percentages of the

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*Indian Crop Calendar, Ministry of Food, Agriculture, Community Development, and Coopration (1967).

†Census Paper I of 1971 (Supplementary), Registrar-General (India).

Table 18.5

Crop Seasons in Indus Basin

Name of crop	Period of	
	Sowing	Harvesting
1	2	3
Jammu and Kashmir		
Rice	April—July	September—November
Wheat	October—November	April—June
Himachal Pradesh		
Rice	June—July	September—November
Maize	April—June	September—October
Potatoes	April—May	September—October
Wheat	October—November	April—June
Punjab and Haryana		
Rice	May—August	September—November
Cotton	May—June	September—December
Wheat	October—December	April—May
Gram	September—November	March—April
Sugarcane	February—April	December—March
Rajasthan		
Wheat	October—December	March—May
Gram	September—November	February—April
Cotton	May—July	October—December

area of each district within the basin to the district as a whole, the total population in the basin is about 24.63 million. The State-wise distribution is shown in Table 18.6.

The towns with a population of more than one lakh each are Srinagar, Jammu, Amritsar, Jullundur, Ludhiana, Ambala, Patiala and Bikaner. The average density of population in the basin is 77 persons per sq. km. The density varies from region to region within the basin. The most densely populated district of Jullundur has 418 persons per sq. km. while the district of Lahaul and Spiti with 2 persons per sq. km. is at the other extreme. 68.7% of the population in the basin live in rural areas and the

Table 18.6

Indus Basin—Statewise Population

State	Population (millions)
1	2
Jammu & Kashmir	4.61
Rajasthan	1.04
Himachal Pradesh	3.11
Punjab	13.46
Haryana	2.15
Chandigarh	0.26
Total	24.63

balance of 31.3% live in cities and towns. The working force constitutes about 30.5% of the population. Nearly 57.1% of the working force is engaged as cultivators, 11.7% as agricultural labourers and the balance of 31.2% is employed on other activities.

Forests and Agriculture

18.23 Forests and agriculture are the mainstay of the people. Nearly 21.3% of the total reporting area of the basin is covered with forests. The forests are of many varieties, such as spruce, fir, deodar, pine and sal. The area annually cropped in the basin is about 9.32 million hectares, out of which 4.74 million hectares are irrigated, growing mainly wheat, rice, cotton, gram and maize.

Power

18.24 The Central Water and Power Commission has conducted surveys to assess the hydroelectric potential of the country and has worked out the hydroelectric potential of the Indus basin as 6,582 MW at 60% load factor. At present the demand for the electrification of towns and industries is almost entirely met by means of hydro-power stations. There are major hydro-power stations at Bhakra, Ganguwal, Kotla, Jogindernagar, Jammu, Mohora and Gandarbal. The details of power projects under operation and construction in the basin are shown in Table 18.7.

Mineral Wealth

18.25 The principal minerals found in the basin are:

Coal: From Jangalgali in the east to Kalakot in the west in the Jammu province of Jammu & Kashmir as well as in the Bikaner district of Rajasthan.

Gypsum: In Buniyar in Jammu & Kashmir, Rajban in Himachal Pradesh and Bikaner in Rajasthan. Deposits of sandstone are also found in Bikaner.

Bauxite: In the Reasi & Poonch area of the Jammu province of Jammu & Kashmir.

Limestone: In the Kangra and Sirmur districts of Himachal Pradesh, the Ambala district of Haryana and over a greater part of Jammu & Kashmir.

Slate: In the Kangra and Mandi districts of Himachal Pradesh; it is utilised locally for roofing.

Salt: Rock salt deposits in the Mandi district of Himachal Pradesh.

Table 18.7

Power Projects—Indus Basin

Name of the Station	Installed Capacity (MW)	
	Hydro	Thermal
1	2	3
Bhakra Project		
(a) Bhakra Left Bank Power House	450.00	—
(b) Ganguwal	77.00	—
(c) Kotla	77.00	—
(d) Bhakra Right Bank Power House	600.00	—
Beas Unit I	990.00	—
Beas Unit II	240.00	—
U.B.D.C. Hydel Project	45.00	—
Extension of Shanan Power House	100.00	—
Bhatinda	—	220.0
Basi	45.00	—
Jogindernagar	48.00	—
Gandarbal	15.00	—
Mohora	11.40	—
Lower Jhelum	112.00	—
Sumbal (Sindh I & II)	22.00	—
Chenani (Tawi I & II)	23.30	—
Jammu	1.00	—
Salal	540.00	—
Kalakot	—	22.5
Total	3,396.70	242.5

In addition to the above, graphite deposits occur in Jammu & Kashmir, asbestos in Himachal Pradesh and kyanite in both these States.

Industries

18.26 The important industries in the basin are:
Textile and cotton at Amritsar and Ludhiana; woollen mills at Srinagar, Gurdaspur and Amritsar; silk and other fabrics at Srinagar, Amritsar, Ludhiana and Ganganagar; sugar mills at Amritsar, Phagwara and Ganganagar; vegetable oils at Amritsar and Jagadhari; essential oils at Jammu, Amritsar and Nahan; paper mills at Jagadhari; cement at Surajpur; automobile parts at Jullundur, Ludhiana and Ambala; agricultural equipment at Jammu, Batala, Amritsar, Jullundur, Mandi and Nahan; machinery and machine parts at Batala, Ludhiana, Amritsar, Jullundur and Jagadhari; chemical works at Amritsar and Jagadhari; fertilizers at Nangal; and drugs and pharmaceuticals at Patiala, Ferozepur, Ludhiana, Jagadhari, Amritsar, Jullundur, Dharamsala and Bikaner.

Communications

18.27 The basin is served by the network of the Northern Railway with its headquarters at New Delhi. The Punjab and Haryana States are served by broad-gauge lines, with the Delhi-Ambala-Jullundur-Amritsar-Pathankot line as the most important. There are many branch lines in these States connecting the various important towns. Suratgarh, Hanumangarh and Bikaner in Rajasthan are served by metre-gauge only. In Himachal Pradesh the only two lines are the Kalka-Simla and the Pathankot-Jogindernagar lines covering less than 100 km. Both are narrow-gauge. Jammu & Kashmir has only 6 km. of railway line from Madhopur to Kathua. Pathankot is the most important rail-head both for Jammu & Kashmir as well as the western Himachal Pradesh.

The main National Highway runs from south to north connecting Delhi with Srinagar via Ambala, Ludhiana, Jullundur, Pathankot, Jammu and Udhampur. Jullundur-Amritsar, Ambala-Simla-Rampur are National Highways. The latter is known in Himachal Pradesh as the Hindustan-Tibet Road passing through the Mahasu district. Delhi to Fazilka *via* Hissar is also a National Highway serving the Indus basin. In addition, there are State and District roads connecting the important towns in the different States of the basin right up to the Indo-Pakistan border.

Some navigation by small country boats is practised in Jammu & Kashmir. The Jhelum is navigable from Khanabal to Khadanagar, a distance of 158 km.* The Pohru is navigable from Drugmulla to its confluence with the Jhelum at Doabagh, a distance of 58 km., the Sind from Ganderbal to its confluence with the Jhelum at Shadipur, a distance of 18 km. and the Chenab from the Akhnoor Bridge to the Indo-Pakistan border—a distance of 13 km. The Ravi is navigable during the monsoon by country boats from Madhopur to its junction with the Ujh, a distance of 39 km. and the river Sutlej is navigable from Nangal to Rupar Headworks, a distance of 64 km., though no navigation is practised at present on these two rivers.

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*Navigable Waterways of India, Central Water and Power Commission (1961).

In general, the plains of Punjab, Haryana and Rajasthan are better served with communications than the hill States of Jammu & Kashmir and Himachal Pradesh which badly lack communication facilities.

The economy of the basin largely depends on agriculture. The vast fertile plains of the basin are suitable for the cultivation of a variety of crops and the potential for development and diversification of agriculture is very great. The progress in the basin as a whole in the first three Plans has been very satisfactory and even exceptional in Punjab, which has earned a name for its small scale industries.

WATER RESOURCES

Surface Waters

18.28 The surface water potential of the Indus river system has been assessed at different times by different authorities. The very first assessment was made by the Indian Irrigation Commission (1901–03), on the basis of the detailed observations made by the Indus River Commission. According to the above assessment, the total annual surface flow in the Indus and the Luni river systems together was estimated at 165,654 m. cu. m.*

In 1949, when the basin-wise assessment of the water resources of the country was made on the basis of Khosla's empirical formula, the annual runoff of the Indus river system, in India, was assessed as 76,907 m. cu. m.†

In 1960 while making irrigation potential studies, the Central Water and Power Commission had adopted the same figure of 76,907 m. cu. m. as the total annual runoff of the Indus basin in India.‡

18.29 The systematic observations of discharges on the Indus and its tributaries was taken up by the then State Government of the undivided

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*Report of the Indian Irrigation Commission (1901-03).

†An appraisal of the water resources by Dr. A. N. Khosla, UNESCO.

‡Report of technological possibilities of irrigation projects in India, Central Water and Power Commission (Unpublished).

Punjab in the year 1921. In India, the runoff of the Punjab rivers viz. the Ravi, the Beas and the Sutlej have been gauged at the foot-hills ever since 1921–22. The mean values as worked out on the basis of 25 years' average for the period 1921–22 to 1945–46 which has been a somewhat dry cycle and hence more dependable for purposes of planning, are shown below:

(i) River Ravi (at Madhopur)	7,993 m. cu. m.
(ii) River Beas (at Mandi)	15,961 m. cu. m.
(iii) River Sutlej (at Rupar)	16,072 m. cu. m.

This makes a total of 40,026 m. cu. m. This does not take into account the contribution of the catchments of these rivers in the plains area of the Punjab.

18.30 In Jammu & Kashmir, calculated on the basis of the replies of the State Government to the Questionnaire issued by the Irrigation Commission, the average flow for the period 1942–62 of the Jhelum at Baramulla has been assessed as 8,012 m. cu. m. The average flow of the Chenab for the period 1967–69, at Dhamkund, has been assessed as 22,717 m. cu. m. The average flow for the Ujh river, a tributary of the Ravi for the period 1959–63, has been worked out as 1,443 m. cu. m. and of the Basantor river, another tributary of the Ravi, as 42 m. cu. m. for the period 1964–70. Similar figures in respect of the Indus proper are, however, not available. The seasonal variations in flow of the various rivers in the Indus basin are shown below: *

Table 18.8

Seasonal Flows of Rivers—Indus Basin

Name of the river	Percentage of the annual mean flow during			
	April-June	July-September	October-December	January-March
1	2	3	4	5
Indus	31	54	8	7
Jhelum	44	36	8	12
Chenab	28	56	7	9
Ravi	30	51	8	11
Beas	15	67	10	8
Sutlej	23	62	9	6
All rivers together	30	54	8	8

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*Mountains and Rivers of India, 21st International Geographical Congress, India (1968).

Discharge data is available for the Ghaggar at Gumthala for the years 1956 onwards; for the Tangri at Narwana Branch crossing for the years 1959–60 and 1964 to 1968; for the Markanda at Narwana Branch crossing (the Jalbera regulator) for the years 1959–60 and 1963–68, and 1954–60 and 1963–67, respectively; for the Saraswati at the Narwana Branch crossing for the years 1963 to 1966. The Chautang is a flashy torrent and its flood waters have been diverted to the river Yamuna at four points to remove drainage congestion. The total runoff of the Ghaggar river system is estimated to be about 2,159 m. cu. m.

Ground Water

18.31 According to the Geological Survey of India, the ground water divide between the Indus and the Ganga drainage systems passes in a south-westerly direction from south-east of Ambala.* The area to the west of this divide has been taken as the Indus Ground Water Basin. The sediments in this basin are, by and large, coarse than those of the Ganga basin lying to the east of the divide. The greater part of the Indus basin is occupied by Newar alluvial deposits which attain considerable thickness. The ground water exploration in this basin has been done down to a depth of about 500 m. below land surface. However, most of the irrigation tubewells are sunk to within 300 m. of the land surface. The ground water studies carried out in this basin indicate that, by and large, the alluvium down to a depth of about 300 m. is sandy. The sand beds are sources of large supplies of ground water. In the areas bordering the Himalayan foothhills and around Ambala the sediments are predominantly clayey. Though moderate supplies of ground water are obtainable from these areas, they are not considered suitable for heavy duty irrigation tubewells.

18.32 The Geological Survey of India has carried out hydro-geological studies in the Indus basin. Areas of 5,658 sq. km. in Jammu and Kashmir, 2,200 sq. km. in Himachal Pradesh, 25,510 sq. km. in Punjab, 13,058 sq. km. in Haryana, 112 sq. km. in Chandigarh and approximately 400 sq. km. in the Bikaner district of Rajasthan have been covered. This makes a total of 46,938 sq. km., which is about 13.5% of the drainage area of the basin.

18.33 In Kashmir, the valley-fill is composed of the pleistocene Karewa formations overlain partly by the recent alluvium of the Jhelum.

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*Ground Water Resources of India, Status and Surveys, Prospects and Perspectives, Geological Survey of India (August, 1970).

The nature, extent and thickness of these alluvial sediments afford favourable conditions for the development of ground water. Numerous natural springs occur as a result of effluent seepage of ground water in the fringes of the alluvial tract towards the encircling mountain ranges. These springs have got sufficient discharge (400 to 27,000 litres per hour) to be reckoned as potential sources for local water supply. Near-surface ground water, particularly in the Jhelum alluvium, occurs within three metres below ground level. The studies so far carried out in the Kashmir valley warrant a systematic surface and sub-surface exploration for the appraisal of ground water conditions in the valley.

18.34 In Himachal Pradesh, areas where open percolation wells can be successfully installed, are extremely scarce. Such wells have primarily been dug for drinking purposes, but they can afford irrigation to small plots of land especially in the low hill zone extending over Paonta tehsil of the Sirmur district, the Balh area of the Mandi district, the Bhatiat tehsil of the Chamba district and the Bilaspur district where the underground resources appear to be adequate and where the strata is not hard rock. Like open wells, the possibilities for drilling tubewells also exist in the Paonta valley. As a result of exploratory drilling, three tubewells at Dhaulakuan, Majra and Paonta Sahib were energised in 1965 and are being maintained by the PWD. Some more tubewells are proposed in this valley.

18.35 Punjab possesses large resources of underground water suitable for irrigation, except in some areas like the district of Bhatinda and some parts of the Ferozepur and Amritsar districts where the sub-soil water is saline. Due to the presence of alluvium, a large scale programme for tubewells/pumping sets installation can be undertaken without any risk of overdraft on the aquifers which will get augmented from the perennial rivers passing through the State as well as recharge from rainfall and canals etc. An area of about 0.6 to 0.8 million hectares, suffers from waterlogging. The installation of tubewells would not only help to provide assured supplies to the cultivators for intensified cropping but would also solve the waterlogging problem to some extent.

18.36 Ground water exploration in the State of Haryana in the past has been done entirely by the Exploratory Tubewells Organisation of the Government of India up to the end of Third Five Year Plan. 48 exploratory bores were drilled in the State by the Exploratory Tubewells Organisation out of which only 5 exploratory bores were successful. From March, 1968 onward exploration work is being done by the State Exploration Cell in addition to that being done by the Exploratory Tubewells

Organisation. While the Exploratory Tubewells Organisation continues to do extensive exploration work, the exploration work by the State Cell has been oriented towards delineating the sweet-water boundaries, working out the safe yield and assessing the extent of the areas.

EXISTING DEVELOPMENT

18.37 One of the earliest irrigation works undertaken in the Indian portion of the Indus basin was the Bari Doab Canal from the river Ravi in the Punjab State in 1851 by Mr. Dyas of the Bengal Engineers. It was later renamed the Upper Bari Doab Canal after the construction of the Lower Bari Doab Canal (now in Pakistan) in 1913. The canal, without any permanent headworks or distributary channels, was opened in 1859. Its permanent headworks at Madhopur were commissioned in 1876. Built at a cost of Rs. 22.66 million, the canal benefits an area of 0.335 million hectares in the Gurdaspur district.

18.38 Another notable project, the Sirhind Canal was undertaken in the Punjab in 1873. It was the first project in India to be financed from public loan funds and constructed solely by Government agency. It was opened for irrigation in 1882 and cost Rs. 26.87 million. It served 0.60 million hectares lying in British Punjab as well as the erstwhile Princely States of Patiala, Malerkotla, Jind, Faridkot, Nabha and Kalsia —a good example of inter-State co-operation. The Sirhind Canal takes off from the Sutlej river at Rupar, a town about 80.5 km., downstream of the Bhakra Dam. In 1954, the old weir was remodelled into a barrage and another canal, the Bist Doab Canal, was constructed for the irrigation of areas on the right side of the river.

18.39 The First Indian Irrigation Commission had not recommended any specific projects to be taken up for construction in that part of the Indus basin which is now in India.* However, it made a strong plea for leaving the waters of the Beas and the Sutlej free for the irrigation of areas on the left bank of the latter (i.e. southernmost Punjab, Rajputana etc. which now form part of India) instead of utilising the same for the Lower Bari Doab Canal on the right bank for irrigating areas now lying in Pakistan. It recommended that these latter areas should be irrigated by diversion of the waters of the Jhelum and the Chenab. The deliberations of the Commission led to the development of the Triple Canals Project and later on of the Sutlej Valley Project.

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*Report of the Indian Irrigation Commission (1901-03).

18.40 The Ranbir Canal was constructed in 1904 at a cost of Rs. 4.86 million in the Jammu province of the Jammu & Kashmir State to benefit an area of 54,410 hectares.

18.41 Another great canal, the Eastern Canal, was constructed at a cost of Rs. 82.79 million in Punjab between 1927 and 1933. It takes off from the weir constructed across the river Sutlej at Ferozepur and benefits an area of 0.141 million hectares in the Ferozepur district.

18.42 The construction of the Gang Canal in 1927 was the first major scheme of irrigation development in the Rajasthan portion of the Indus basin. The canal takes off from the river Sutlej at the Ferozepur Barrage on the left bank, just upstream of the head regulator of the Eastern Canal. It was the first large canal to be lined in India. Built at a cost of Rs. 33.20 million the canal benefits an area of 0.303 million hectares in the Bikaner district.

18.43 After the partition of the country in 1947, great emphasis was laid on irrigation and power development in the Indus basin and many works were taken up. The most important of these are the Bhakra-Nangal Project, the Harike Project, the Beas Project—Unit I (Beas Sutlej Link) and Unit II (Pong Dam) and the Rajasthan Canal. These are described in the following paragraphs.

Bhakra-Nangal

18.44 The Bhakra-Nangal is one of the largest multipurpose projects in the country. It consists of two projects (Bhakra and Nangal) merged into one, the 'Nangal' part of which was completed in 1952 and the 'Bhakra Dam' in 1963. The Bhakra Dam is a concrete structure of the straight gravity type built across the river Sutlej at the foot of Siwalik Hills in Himachal Pradesh. Its maximum height is 226 m. and its length 518 m. The Nangal Barrage has been constructed about 13 km. downstream of the dam. The Nangal Barrage feeds the Nangal Hydel Canal which takes off just upstream of the barrage on the left bank of the river. The canal is fully lined throughout its entire length of 64.4 km. and is designed to carry a maximum discharge of 354 cumecs. It serves as a feeder for the Bhakra Canal System below Rupar and for generating power at the power stations at Ganguwal and Kotla, at 19.3 km. and 28.9 km. respectively, from the head of the channel. A third power station is proposed to be built later on the hydel channel. The Bhakra Canal System has been planned to serve the arid tracts of Punjab and Haryana and a part of the Bikaner district of Rajasthan, which are drought areas. The Bhakra Canal System comprises the following distinct schemes:

(i) Construction of the Bhakra Canals, fed by the 354 cumecs hydel channel.
(ii) Enlarging the capacity of the old Sirhind Canal by over 99 cumecs by remodelling the Rupar Headworks and the old canal.
(iii) Construction of the Bist Doab Canal, taking off on the right bank of River Sutlej at the Rupar Headworks, with a discharge of 39.6 cumecs.

The whole system utilizes a discharge of about 509.7 cumecs over a length of 1,110 km. of main canal and branches and 3,379 km. of distributary channels. The total area benefiting from the three parts of the project is nearly 4 million hectares out of which about 2.4 million hectares are new areas. Though construction work on the canal system was completed in 1954, it started taking restricted supplies for kharif irrigation from 1952. The Ghaggar Canal System taking off from the Ottu Weir built in 1899 at a cost of Rs. 1.224 million and benefiting an area of 30,307 hectares is also integrated with the Bhakra System.

Beas Project

18.45 The waters of the three eastern rivers namely the Sutlej, the Beas and the Ravi have been allotted to India under the Indus Waters Treaty of 1960. The Beas Project has been undertaken for harnessing the water and power resources of the river Beas by means of storage and diversion works. The project which will benefit Haryana, Punjab and Rajasthan consists of two parts: Unit No. I—Sutlej-Beas Link; and Unit No. II—the Pong Dam on the river Beas.

(i) Unit No. I (Sutlej-Beas Link) comprises a diversion dam at Pandoh across the Beas in the Kulu valley to transfer 4.589 m. cu. m. of water to the Bhakra reservoir through tunnels and open conduits. This will make up any shortage of water in the Bhakra reservoir and provide canal irrigation in Gurgaon and other southern districts of the Haryana State. A natural fall of 305 m. available at Dehar will be utilized for the generation of power.

(ii) Unit No. II (Pong Dam) envisages the construction of an earth-cum-gravel dam on the river Beas in the Kangra district. The dam will be 100.6 m. high and will release regulated supplies of water into the Rajasthan Canal and the Punjab Canal System emanating from the Harike Headworks. The water so released will also be utilised for the generation of power in a power house downstream of the Pong Dam.

Rajasthan Canal Project

18.46 The project provides for the construction of a canal which takes off from the Harike Barrage across the Sutlej river. The first 178.3 km. of the canal are in Punjab and Haryana and the balance 506.8 km. in Rajasthan. Its capacity at the head will be 509.7 cumecs. The first 216 km. of the canal are called the Feeder and the remaining 469.1 km. are termed as the Main Canal. About 1,264,280 hectares in the Bikaner and Jaisalmer districts will be benefited by this project. It has been decided to line the main canal in order to save absorption losses in the sandy reaches. Besides the Rajasthan Feeder, the main canal has also been completed up to 77 km. along with the allied distributaries. About 97,128 hectares received irrigation by March 1969.

Appendices 18.1, 18.2 show the details of the major and medium projects under operation and construction in the basin.

18.47 Besides the major and medium projects, minor schemes comprising Kuhls (small private channels) specially in Himachal Pradesh and Jammu & Kashmir, open wells, tubewells and tanks irrigate a large area in the basin. The details of the area irrigated by the various sources like canals, wells, tanks etc. during the year 1967–68, State-wise in the basin are given below:

Table 18.9
Sourcewise Irrigation—Indus Basin

(Thousand hectares)

Source of Irrigation	Name of State/Union Territory						
	Punjab	Haryana	Himachal Pradesh	Rajasthan	Jammu & Kashmir	Chandigarh	Total
1	2	3	4	5	6	7	8
Canals	1,291.4	207.5	0.1	351.9	274.6	N.A.	2,125.5
Tanks	—	0.3	—	—	0.5	N.A.	0.8
Tubewells	620.4	1.5	—	—	Neg.	N.A.	621.9
Open wells	411.5	38.1	0.8	—	1.5	N.A.	451.9
Other sources	7.2	4.3	83.1	—	7.3	N.A.	101.9
Total	2,330.5	251.7	84.0	351.9	283.9	N.A.	3,302.0

The area under minor schemes increased by about 48,300 hectares in 1968–69.

18.48 In the absence of data regarding the annual diversion and utilisation by the major and medium projects under operation and construction in 1968–69 in the basin, the utilisation has been approximately estimated by the Commission. On completion and full development these projects are expected to utilise 39,596 m. cu. m.

18.49 No information is available regarding the statistics of the large number of minor schemes comprising diversion tanks, tubewells and wells. Based on the area irrigated from these sources and on rough duties, an approximate estimate of the quantity of water diverted for irrigation by these works has been made. On completion and full development the minor schemes under operation and construction in 1968–69 would use about 9,329 m. cu. m.

The Commission does not express any view on the correctness of the duties and would like to emphasise that the estimates of the area irrigated and the water diverted by the projects are very rough.

Reservoir Losses

18.50 On the basis of assumptions detailed in para 1.33 the reservoir losses from the various schemes in the basin will be as under:

(i) Major and Medium Schemes	5,629 m. cu. m.
(ii) Minor Schemes (tanks)	9 m. cu. m.
Total	5,638 m. cu. m.

18.51 The total utilisation, including reservoir losses, by the major, medium and minor projects undertaken up to the beginning of the Fourth Plan, on their completion and full development would be of the order of 54,563 m. cu. m., of which 46,048 m. cu. m. is from surface water and 8,515 m. cu. m. is from ground water.

The data on the industrial needs of the basin are not readily available. So far, pollution of water by industrial wastes has not been reported.

FUTURE DEVELOPMENT

18.52 The future development of irrigation in the Indus basin is governed by the various provisions and stipulations made in the Indus

Waters Treaty, 1960. It may, therefore, not be out of place to mention, in brief, some fundamental points relevant to the Treaty which governs the use of the Indus Waters.

According to the Treaty* all the waters of the Eastern rivers (the Ravi, the Beas and the Sutlej) shall be available for the unrestricted use of India except as otherwise expressly provided in Article-II. Similarly, Pakistan shall receive for unrestricted use those waters of the western rivers (the Indus, the Jhelum and the Chenab) which India is under obligation to let flow without any interference with these waters except for some specific uses such as domestic, non-consumptive, generation of hydroelectric power and the irrigation of certain areas,—as outlined in Annexures C, D & E of the Treaty.

According to Clause 4 Annexure C [Article III (2)(c)] of the Indus Waters Treaty, an area of not more than 40,470 hectares can be supplied irrigation water from the Chenab in the Jammu district. This is in addition to withdrawals from the Ranbir and the Pratap Canals, governed by Clause 3 of Annexure 3. As for the Ravi, the share of Jammu & Kashmir has been fixed at 1,048.46 m. cu. m. The 'Ravi-Tawi Lift Irrigation Scheme' has been formulated to irrigate the land between the Ravi and the Tawi (a tributary of the Chenab), the boundaries of which are the lower Siwaliks on the east and the Indo-Pakistan border on the west. The scheme when completed will utilise the supplies of the Tawi, the Ujh and the Ravi, available to the Jammu & Kashmir State. Phase-I of the scheme viz. Tawi Lift Irrigation Scheme is included in the Fourth Plan and work on it has been taken up in hand. The project will benefit 12,141 hectares in the Jammu region at a cost of Rs. 51.70 million and will use 93 m. cu. m. annually. Appendix 18.3 shows the details of this project.

18.53 No new major or medium scheme in the States of Himachal Pradesh, Punjab, Haryana (including Chandigarh) and Rajasthan falling in the basin has been included in the Fourth Plan.

By the end of Fourth Plan, the area under minor schemes is expected to increase by about 738,670 hectares requiring nearly 5,632 m. cu. m. of water, including losses.

18.54 Thus, with the additional utilisation by the Fourth Plan Projects, about 60,288 m. cu. m. of the waters (46,638 m. cu. m. of surface waters + 13,650 m. cu. m. of ground waters) would be used for irrigating a total area of about 7.17 million hectares.

Keeping in view the various provisions and limitations of the Indus

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*The Indus Waters Treaty (1960).

Waters Treaty 1960, the State Governments concerned have shaped their programme of future development.

18.55 Of the three rivers serving the State of Punjab, the waters of the Sutlej have already been exploited by the construction of the Bhakra-Nangal Project. Work on the Beas Project Units I & II is in full swing. When completed, this will also tap practically all the water available in the river. The waters of the river Ravi have not been exploited in full as yet. There is a proposal for a multipurpose project namely the Thein Dam Project across the Ravi for the development of irrigation, power, flood control, recreation facilities and for pisciculture. The project provides for the construction of a 147.01 m. high thick-core gravel shell dam across the river Ravi near village Thein in Jammu & Kashmir State. The dam site is about 24 km. by road from the Madhopur Headworks. A power plant is also proposed to be built near the Thein Dam. The construction of a dam on the Ravi, in the view of the State Government, is essential for the utilisation of the irrigation and power potential which has fallen to the share of India under the Indus Waters Treaty. The additional supplies available from the Thein Dam will be utilised for improving the capacity factor, and water allowance and for extending irrigation to new areas. There will be an increase of 348,657 hectares of annual irrigation due to the project which will also yield 315 MW of power at 60 per cent Load Factor.

18.56 There is very limited scope in the State for providing irrigation on an extensive scale through new major and medium irrigation projects. The main schemes proposed to be taken up in future are given below:

(i) Utilisation of surplus Ravi-Beas waters released under the Indus Waters Treaty.
(ii) Extension of non-perennial irrigation to areas in the Upper Bari Doab Canal.
(iii) Sinking of tubewells in the Upper Bari Doab Canal Tract for stabilizing and augmenting supplies in winter.

These are described in the following paragraphs.

18.57 The utilisation of surplus Ravi-Beas waters released under the Treaty: A scheme has been formulated to synchronise with the completion of the Beas Project so as to enable the utilisation of the stored supplies and also the supplies withdrawn from Pakistan under the Indus Waters Treaty. It has two distinct components namely, (a) construction of a link from the Sutlej River to the Narwana Branch (this now concerns Haryana State) and (b) extension and remodelling of the existing Bhakra and Sirhind Canal systems. The project will create a total irrigation potential of 81,000 hectares during the Fourth Plan period.

18.58 The extension of non-perennial irrigation to areas in the Upper Bari Doab Canal Tract: As a result of the Indus Waters Treaty, India has been given the use of the entire water of the river Ravi. The Punjab State is contemplating to use 2,467 m. cu. m. out of the waters of this river in the Upper Bari Doab Canal tract. The anticipated irrigation would cover 146,000 hectares.

18.59 Sinking of tubewells in the Upper Bari Doab Canal tract for stabilizing and augmenting the supplies in winter: During the rabi season, the water supplies available from the river Ravi are sufficient to meet only about 25 to 50 per cent of the irrigation requirements of the Upper Bari Doal Canal tract. Even after the completion of the Thein Dam, the position in this tract is not likely to improve much. This scheme envisages the installation of about 300 deep tubewells in the Upper Bari Doab Canal tract to augment the lean water supplies in winter and also to guard against the rise of the sub-soil water table in this tract. With the implementation of this scheme, about 40,000 hectares of land will be provided with irrigation facilities.

18.60 In order to assure an adequate supply of water for encouraging high yielding varieties and raising an extra crop on the Gang and the Bhakra Canals, the Rajasthan Government has the following projects under contemplation:

Table 18.10

Future Projects in Rajasthan Area of Indus Basin

Project	Total estimated cost (Rs. million)	Area proposed to be irrigated (hectares)
1	2	3
Increasing irrigation potential on the Gang Canal system	26.0	101,000
Increasing irrigation potential on the Bhakra canals	30.0	125,000
Creating potential for rice cultivation on the Bhakra canals	3.0	8,100

18.61 In addition to the above, the Rajasthan State has also investigated two major projects to serve areas in the Ganganagar district. These are (i) the Sidhmukh project to benefit 75,600 hectares at a cost of Rs. 6.45 million and (ii) the Nohar project to benefit 54,720 hectares at a cost of Rs. 70.85 million. The source of supply for both projects is the Bhakra Canal.

18.62 The Haryana Government has also investigated the following projects to be benefited from the surplus Ravi-Beas waters.

Table 18.11

Future Projects in Haryana Area of Indus Basin

Project	Name of the river	Area proposed to be irrigated annually (hectares)
1	2	3
Sohna Lift Irrigation Scheme (Stage II & III)	Yamuna & Ravi-Beas waters	78,700
Nohar-Salawas Lift Scheme	Ravi-Beas	6,300
Dadri Lift Irrigation Scheme	,,	15,300

18.63 Link works to transport the Ravi-Beas water to the Western Yamuna Canal: The Haryana State has a share in the waters of the Ravi and the Beas. On completion of Unit I of the Beas Project, the water from the Beas will be carried to the Gobindsagar lake and thence to the Bhakra and the Western Yamuna Canal Systems. The supplies are expected to become available sometime during 1974. It is, therefore, vital that channels for transporting the Beas water from the Sutlej sub-basin to the Western Yamuna Canal are completed simultaneously. A project for the construction of a link channel of 196 km. length with 190.32 cumecs capacity has been prepared at an estimated cost of Rs. 270 million. The proposed link channel will take off at a point about 32 km. upstream of Rupar town and run parallel to the Bhakra Main Line, the Narwana Branch and the Narwana Branch-Karnal link up to its outfall in the Western Yamuna Canal near Karnal. The link when completed will provide an increased water allowance to the areas already commanded by the Bhakra and the Western Yamuna Canal systems. It will also provide irrigation to new areas in the Mahendragarh, Rohtak and Hissar districts.

The Jammu & Kashmir State has proposals to take up a Lift Irrigation Scheme from the Manawar Tawi (21.34 m. lift) for irrigating 6,880 hectares in Chhamb Niabat and on the Pargoal island situated in the Chenab.

Appendix 18.4 shows the details of the above projects.

FLOODS, WATERLOGGING AND DRAINAGE

18.64 Floods in Kashmir are due to spates in the river Jhelum which runs across the valley for over 188 km., draining a catchment of 12,850 sq. km. When in spate, the river overflows its banks inundating the cultivated lands, particularly on the left bank between Srinagar and Sangam and on both banks below Srinagar up to Banyari over a distance of 143 km. Between the years 1900 and 1965, 15 major floods have been experienced in the valley. During the period between 1950 and 1965, major floods occurred in each of the years 1950, 1954, 1957 and 1959. The flood of 1959 is considered to have been the highest ever recorded. Damage to public utility services was about Rs. 20 million, in addition to Rs. 15.6 million of damage to crops.* The maximum discharge recorded at Sangam in 1957 was of the order of 2,689 cumecs.**

18.65 The main reason for the flooding of the Jhelum is the inadequate outflow capacity of the river below the Wular Lake. During 1959 when the highest ever recorded flood occurred, the outflow capacity of the river was hardly 1,007 cumecs while the inflow into the lake was of the order of 3,962 cumecs. The surplus water which could not escape, spilled over the banks and caused widespread damage. To overcome this problem, a master plan was drawn up in 1960 in which an outfall channel was proposed to check the river's propensity for overflowing its banks. This project is the most important of the State schemes for flood control in the Kashmir valley and the State Government expects to complete it during the Fourth Five Year Plan. On completion, the outfall capacity of the river from the Wular lake is expected to be doubled.

18.66 Unlike in the Kashmir valley, the problem in Jammu is mainly due to soil erosion. A large number of protective works are proposed to be taken up during the Fourth Plan.

There is no major flood control problem in Himachal Pradesh. A sum of Rs. 20 million has, however, been provided under the Fourth Plan for the following schemes:

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*Report of the Ministers Committee on Flood Control, Ministry of Irrigation and Power (1964).

**Report of the High Level Committee on Floods, Ministry of Irrigation and Power (1958).

(i) Flood control works on the Markanda in the Sirmur district.
(ii) Flood control works on the Bata Nadi.
(iii) Flood control works in the Balh valley.
(iv) Flood control works in the Kulu valley.
(v) Reclamation of land from Ray to Kudubela in the Kangra district.

18.67 The rivers Ravi, Beas and Sutlej traverse the alluvial plains of Punjab in a generally south-westerly direction. In addition, there are many small hill torrents and 'Choes' which spill into the plains, in floods during the rainy season. The flood problem in the State is aggravated by the sudden change in gradient as the rivers emerge from steeply sloping mountain valleys into gently sloping plains.

18.68 The damage caused by floods to crops and property in the reorganised State of Punjab is given below:

Year	*Rs. million*
1955	310.5
1956	9.8
1957	19.3
1958	203.3
1959	17.9
1960	123.0
1961	47.7
1962	310.9
1963	5.9
1964	152.0
1965	0.2
1966	91.6
1967	27.0

18.69 In the Ganganagar district of Rajasthan, flood damage has been experienced since 1956 due to increase in the intensity and duration of flow of the Ghaggar river from its catchment area in Punjab and Haryana. The yearwise figures of the irrigated areas of the Bhakra, Bikaner and Rajasthan Canal commands lying in Rajasthan which have been flooded by the river Ghaggar are given on page 465.

Year	*Area flooded* (*hectares*)
1964	54,750
1965	34,500
1966	48,600
1967	32,400
1968	39,700

18.70 To protect these valuable irrigated areas from flooding, a flood control scheme has been executed at a cost of about Rs. 40 million. Under this scheme a diversion channel 51 km. long with a design discharge of 339.6 cumecs has been constructed to divert the flood waters into a number of depressions in sand dunes south of the irrigated belt. The total capacity of these depressions is 949.78 m. cu. m. which is the normal monsoon run-off carried by the river at present. If the flood discharge at any time is more than 339.6 cumecs and the total run-off received in a season is more than the capacity of the depressions, the water will have to be released into the Ghaggar bed. Such releases would be infrequent and the water so released would saturate the bed and facilitate rabi cultivation after the bed dries up through evaporation and deep percolation. Although the Ghaggar diversion channel does not ensure complete protection to the flood plains against monsoon flooding, it safeguards the area against winter floods, which are shorter in duration and small in size, and thus guarantees the cultivation of rabi in the area.

18.71 The Kashmir valley is covered by waterlogged areas and a large number of swamps called 'Numbals'. The problem of waterlogging is predominant in the Sonarwari area. Attempts have been made from ancient times to reclaim this land by building levels and embankments. The level of the lands here has thus remained unaltered whereas the levels of the surrounding rivers and lakes have risen steadily. This increases waterlogging in these areas and renders them unfit for cultivation. The problem of waterlogging has been tackled successfully by installing a battery of dewatering pumps along the embankments. The installation of these dewatering stations as well as dewatering-cum-irrigation stations has made possible the reclamation of a sizeable area in addition to extending irrigation by the use of the pumped out water. Similar projects are being undertaken in other waterlogged areas.

18.72 Punjab is primarily an agricultural State. The recurrence of floods has a direct bearing on the extent of waterlogging in agricultural lands. Apart from seepage from irrigation canals and irrigated lands there are other important factors contributing to the rise of the ground water table such as the construction of embankments for canals, roads, railways etc. drainage without adequate waterways for cross drainage works. The continued deforestation of the hills has caused frequent flash floods in the rivers, hill torrents and 'Choes' often flood large areas. The total waterlogged areas in the month of October, during the various years, with sub-soil water within 1.52 m. of the surface are shown below:

Year	*Area in hectares*
1951	363,722
1955	827,368
1956	869,900
1958	1,103,400
1959	1,017,446
1962	1,323,506
1964	970,787

18.73 It has been assessed that flood control and drainage schemes in the reorganised Punjab State would cost about Rs. 800 million and anti-waterlogging schemes about Rs. 440 million. The achievements up to 1968–69 and the targets proposed for the Fourth Plan in respect of flood control, drainage and anti-waterlogging schemes are given below:

	Bunds	Drains
(*i*) Flood control and drainage		
1. Total length of embankments and drains required to be constructed in the re-organised Punjab State.	603 km. Besides, 282 km. reclamation and flood protection bunds will be constructed along the river Sutlej from Rupar to Harike.	10,780 km.
2. Length of bunds likely to be constructed by the end of 1968-69.	410 km. length of bunds including replenishing the bunds. Besides, 249 km. reclamation bunds constructed along the Sutlej.	4,505 km. drains in pilot schemes at intermediary stages.

3. Length of bunds likely to be constructed in the Fourth Plan.	48 km. of bunds and replenishing the bunds previously constructed. Besides, 33 km. remaining length of reclamation and flood protection bunds along the river Sutlej is to be constructed.	1,006 km. new drains and enlarging the capacity of drains and completing other components of schemes spilled over to the Fourth Plan.
(*ii*) Anti-waterlogging		(million hectares)
1. Total catchment area to be benefited in the reorganised Punjab		3.66
2. Catchment area benefited during the Second and Third Plans		1.46
3. Catchment area likely to be benefited during 1966-67 to 1968-69		0.20
4. Catchment area likely to be benefited in Fourth Plan		0.73
5. Spillover		1.27

SOIL CONSERVATION

18.74 The Indus basin has vast hilly areas in Jammu & Kashmir and Himachal Pradesh. Some areas in the plains are also subject to erosion and floods. The adoption of soil conservation measures is, therefore, of paramount importance, not only for increasing and stabilizing agricultural production in the basin, but also for ensuring that the costly storages put up on the rivers Sutlej and Beas do not get silted up sooner than anticipated.

18.75 In Jammu & Kashmir the main problem of soil conservation is in the regions comprising the catchments of the rivers Jhelum, Tawi, Ravi and Ujh where vegetative cover has been greatly depleted due to overgrazing and the breaking up of steep hill sides for cultivation. Faulty tillage methods have also been responsible for the deterioration of soil. Soil conservation problems also exist along the Karewa belt, where deep ravines have been formed by runoff water. The following soil conservation measures have been started since the First Five Year Plan.

(i) Afforestation work
(ii) Fencing
(iii) Minor Engineering works such as gully plugging, nalla terracing, bunding etc.
(iv) Terracing.

In the Fourth Five Year Plan, an outlay of Rs. 42.50 million has been earmarked for the soil conservation programme and the following two schemes have been added to four mentioned above:

(i) Control of erosion on the National Highway
(ii) Development of grass lands for cattle-feed and fodder.

18.76 In Himachal Pradesh the various soil conservation measures undertaken in the agricultural lands are (i) levelling and grading of land, (ii) remodelling of existing terraces, (iii) water disposal and field bunding, (iv) construction of contour strips in orchards and (v) drainage of agricultural lands and reclamation of eroded land along the rivers.

18.77 Under the Centrally Sponsored Programme of soil conservation in catchments of river valley projects, the Pohru Project in Jhelum sub-basin has been included. Up to the end of the Third Plan, with an expenditure of Rs. 2.269 million, an area of 6,000 hectares was treated with soil conservation measures. During the Annual Plans period (1966–69) in an additional area of 1,000 hectares soil conservation measures were undertaken at a cost of Rs. 1.211 million.* With a view to intensify the soil conservation works in the catchments of the rivers Sutlej and Beas and to reduce the silt load carried down to the reservoirs, a scheme was drawn up during the Third Plan period and has been continued during the Fourth Five Year Plan. During the Fourth Plan period an amount of Rs. 87.50 million has been provided for carrying out the following:

(i) Afforestation
(ii) Construction of roads
(iii) Construction of buildings
(iv) Engineering works
(v) Purchase of machinery and equipment
(vi) Silt investigation
(vii) Road-side and stream bank-stabilization and
(viii) Soil conservation investigation and evaluation.

In addition to the above, the Forest Department of Himachal Pradesh Government has also proposed soil conservation schemes amounting to Rs. 30 million. These include (i) soil and water conservation demonstration of water shed, (ii) training of 'Choes', and (iii) soil conservation in the Kinnaur and Lahaul-Spiti districts.

18.78 During the Fourth Five Year Plan, in Punjab, where the problem is less acute, soil and water management programmes will be stepped up and carried out in an area of 126,000 hectares. Of this area, 106,000 hectares will be covered by soil and water management works including the provision of suitable water-conveying systems, land grading works, conservation irrigation, field-drainage etc. An area of 20,000 hectares is proposed to be covered with soil erosion control works like contour bunding, terracing, check dams, gully plugging, excess water disposal structures and other soil and water conservation measures needed in erosion affected areas.

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*India, Irrigation and Power Projects (Five Year Plans), Central Water and Power Commission (April, 1970).

18.79 A capacity survey of the Bhakra reservoir was initiated in 1959–60 and the observations were repeated every year. The reservoir has a gross storage capacity of 9,344 m. cu. m. of which 7,290 m. cu m. is live storage and the balance 2,054 m. cu. m. dead storage. The details of annual siltation during the period 1959 to 1967 are shown below:*

Table 18.12

Silting of Bhakra Reservoir

Year	Sediment deposition in m. cu. m.			Rate of siltation per 100 sq. km. of net catchment area annually in m.cu.m.
	Dead Storage	Live Storage	Total	
1	2	3	4	5
1959 to 1964	114	151	265	0.09
1965	12	13	25	0.04
1966	17	35	52	0.09
1967	19	13	32	0.06
Total for 9 years	162	212	374	—
Annual average	18	24	42	0.07

Note: Yearwise break-up of sediment deposition in the dead and live storages, during 1959-1964, is not available.

The average annual rate of siltation in the reservoir has been of the order of 0.07 m. cu. m. per 100 sq. km. against 0.05 m. cu. m. per 100 sq. km. assumed in the project estimates. Soil conservation measures in this catchment are urgently needed.

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*Sedimentation data on selected reservoirs in India (revised edition), Soil Conservation Directorate, Central Water and Power Commission, March, 1969—Unpublished.

GENERAL

18.80 The Indus and its tributaries are an inter-State river system flowing through the States of Jammu & Kashmir, Himachal Pradesh, Punjab, Haryana and Rajasthan. A number of projects have already been constructed in the basin. Two medium projects in Jammu & Kashmir, two inter-State multipurpose projects and one major project in Rajasthan are under construction.

The distribution and utilisation of the Indus water is governed by the Indus Waters Treaty, 1960. The works under construction in the basin may be completed at the maximum technologically feasible speed so that the water allotted to India are utilised at the earliest. Adequate provision of funds should be made for these works in the State Plans.

18.81 Under the Inter-State Agreement of June, 1955, the composite Punjab State was allocated 8,881 m. cu. m. of Ravi and Beas water, the balance going to Jammu & Kashmir and Rajasthan. After the re-organisation of Punjab, claims and counter-claims to the above waters have been made by the reorganised States. There is, therefore, immediate need for adjustments in the existing Inter-State Agreement.

18.82 The number and distribution of rain-gauge stations should be reviewed and new stations should be established to fill in such gaps as are existing. It is also important that the daily rainfall data for all these stations are published on a monthly basis, preferably sub-basin-wise.

A network of evaporation-measurement stations particularly at the sites of existing and proposed reservoirs needs to be established.

Gauge and discharge observations of the various sites in the basin should be continued on a permanent basis to obtain the data essential not only for the preparation of individual projects but also for the regulation, to the best advantage, of the available river water in any year.

18.83 Systematic and scientific exploratory work is needed for a quantitative and qualitative assessment of the ground water resources in the basin, so that these resources can be exploited in a rational way either independently or in conjunction with surface waters.

18.84 There is need for inter-State co-operation and agreement in respect of soil conservation measures and conserving the storage capacities of existing and proposed reservoirs in the basin.

18.85 It is necessary for systematic data to be collected of the sediment carried by the rivers, which would be of considerable use in working out the dead storages and the lives of reservoirs. It will also reflect the effect of soil conservation works carried out in the basin.

APPENDIX 10.1

Salient Features of Existing Major & Medium Projects in the Brahmaputra Basin

Name of the project	Zone/District	Cost/Total expenditure incurred (Rs. million)	Source of supply (Name of river)	Year of completion	Type (Flow/Storage/Lift)	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Length of main canal & branches (km.)	Whether perennial, two seasonal or one seasonal
1	2	3	4	5	6	7	8	9	10	11
Assam										
Jamuna Irrigation Scheme	Mikir Hills & Nowgong	39.60	Jamuna river	1969	Flow	33.830	27.040	25.690	138.0	N.A.
Patradisha Irrigation Scheme	Mikir Hills	3.362	Patradisha stream, a tributary of river Jamuna	1969	Flow	2.430	1.635	2.430	N.A.	Two seasonal

Source: (i) Replies of Assam Government to the questionnaire issued by the Irrigation Commission.
(ii) Note Volume of Irrigation Chapter for Assam, Central Water and Power Commission (1970)—Unpublished.

APPENDIX 10.2

Salient Features of Major and Medium Projects Under Construction in the Brahmaputra Basin

Name of the project	Zone/ District	Description of the scheme	Time schedule of construction			Cost		Ultimate irrigation ('000 hectares)
			Date of commencement	Important items of work completed	Date of likely completion	Total cost (Rs. million)	Expenditure incurred (Rs. million)	
1	2	3	4	5	6	7	8	9
Assam								
Sukla Irrigation Scheme	Kamrup	Construction of a weir across the Sukla river and a canal system	1965	Staff quarters, office building, collection of boulders and earthwork in canal area are in progress	IV Plan	29.80	3.44	32.640
Harguti Irrigation Scheme	Mikir and North Cachar Hills	Construction of a weir across the Harguti river with a canal on the left bank	1968-69	Preliminary works taken in hand	IV Plan	4.278	0.616	4.047

Source: (i) Replies of Assam Government to the questionnaire issued by the Irrigation Commission.
(ii) Note Volume of Irrigation Chapter for Assam, Central Water and Power Commission, 1970—Unpublished.

APPENDIX 10.3

Details of New Major and Medium Projects Proposed in the Brahmaputra Basin by Various States

Name of the project	Zone/ District	Source of supply (Name of river)	Estimated cost (Rs. million)	Ultimate irrigation ('000 hectares)
1	2	3	4	5
Assam				
Dhansiri Irrigation Project	Darrang	Dhansiri	78.40	46.059
Sirajuli Irrigation Scheme	-do-	N.A.	4.00	3.840
Ninal Irrigation Project	-do-	N.A.	Estimate not yet framed	N.A.
Phulaguri Irrigation Project	-do-	N.A.	3.50	N.A.
Puthimari Irrigation Project	-do-	N.A.	Estimate not yet framed	N.A.
Panchanai Irrigation Project	-do-	Panchanai	-do-	N.A.
West Bengal				
Tista Barrage Scheme	North Bengal/ Darjeeling Jalpaiguri Cooch Behar & West Dinajpur	River Tista (mainly)	832.10	546.330
Sarda Irrigation Scheme	Jalpaiguri	River Sarda	6.25	4.925

Source: Replies of Assam and West Bengal to the questionnaire issued by the Irrigation Commission.

APPENDIX 12.1

Monthly and Annual Normals of Rainfall in the Basin of West Flowing Rivers Between Kanniyakumari and the Tapi

State/District	Normal Rainfall (mm)												Annual Normal Rain-fall in mm
	January	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Gujarat													
Surat	3.2	2.0	0.9	2.5	6.7	240.9	634.1	344.8	229.6	42.4	12.3	1.8	1521.2
Dangs	3.5	1.3	1.1	3.2	10.9	234.9	835.5	506.6	322.3	55.9	20.1	3.5	1998.8
Kerala													
Cannanore	5.3	4.8	11.2	58.6	200.6	923.0	1063.5	584.7	239.4	218.0	106.0	22.8	3437.0
Kozhikode	9.0	6.8	18.4	84.0	233.5	853.9	1005.9	530.5	239.2	286.6	160.1	33.4	3461.3
Palghat	9.1	9.3	26.6	80.0	175.2	532.2	657.1	361.9	175.7	257.4	144.3	30.4	2459.2
Trichur	10.1	9.2	28.4	91.1	283.5	800.3	747.6	441.7	245.5	305.7	163.5	32.8	3159.4
Ernakulam	18.0	23.6	54.4	136.1	310.1	792.1	785.9	523.5	296.6	365.7	216.9	54.6	3577.5
Kottayam	31.2	27.0	59.5	133.1	237.4	585.8	628.0	412.4	263.5	330.8	213.6	72.2	2994.5
Alleppey	27.6	31.6	59.7	134.1	293.7	666.1	548.1	371.3	272.3	328.1	224.0	64.0	3020.9
Quilon	24.1	32.1	83.6	166.3	260.3	547.4	449.6	318.1	226.2	344.9	242.9	64.8	2760.2
Trivandrum	21.2	18.0	48.0	118.1	213.9	391.1	257.4	204.5	168.9	280.2	210.2	70.1	2001.6

Bombay Suburban	3.1	1.3	0.8	2.5	17.3	476.0	725.9	414.8	295.7	75.7	15.7	0.8	2029.6
Bombay	4.1	2.0	1.5	1.5	18.3	464.8	613.4	328.9	286.0	64.5	17.5	2.3	1804.8
Thana	3.1	1.0	0.9	3.9	15.6	413.3	903.1	512.3	303.0	78.9	21.7	1.8	2258.6
Kolaba	2.1	0.9	1.1	3.3	19.1	579.9	1113.9	706.7	396.2	107.1	23.5	2.5	2956.3
Nasik	4.1	1.9	1.6	5.5	19.2	154.1	339.9	221.4	180.0	60.9	28.8	4.6	1022.0
Ratnagiri	3.0	0.5	2.1	8.5	43.7	778.1	1205.9	687.9	412.9	119.8	38.1	5.2	3305.7
Kolhapur	3.3	0.8	8.3	27.8	51.8	316.3	731.2	427.5	198.2	119.1	40.3	6.9	1931.5
Mysore													
South Canara	4.5	2.1	6.9	35.9	149.5	1016.3	1270.2	775.1	339.9	227.8	87.3	16.9	3932.4
Coorg	6.4	5.6	21.9	90.1	145.8	502.6	878.2	515.8	233.9	212.6	93.7	18.9	2725.5
Hassan	5.0	5.4	9.1	52.7	111.3	124.9	245.5	140.7	101.6	153.9	73.7	16.9	1040.7
Shimoga	2.8	2.5	7.0	37.2	75.5	259.4	540.7	283.5	125.4	133.2	47.8	11.3	1526.3
Chikmagalur	3.8	3.7	10.8	53.7	96.5	311.7	693.0	400.7	170.3	165.1	64.1	16.4	1989.8
Belgaum	2.7	1.7	7.9	32.6	56.3	106.5	193.5	118.6	111.5	102.5	41.6	9.3	784.7
North Canara	1.6	1.5	4.3	26.2	78.2	714.1	972.6	528.0	242.7	135.5	50.3	9.1	2764.1
Dharwar	2.1	2.5	6.1	33.1	67.1	86.9	130.0	96.8	103.4	109.8	41.9	11.4	691.1
Tamil Nadu													
Coimbatore	17.4	12.0	20.5	57.3	97.4	109.2	144.4	117.7	105.2	186.2	123.8	39.3	1030.4
Nilgiris	44.9	24.8	31.4	93.8	151.0	232.2	378.9	270.4	179.8	253.1	188.2	72.4	1920.9
Kanniyakumari	25.5	21.5	54.0	115.4	143.1	227.7	132.1	89.4	97.0	259.1	232.7	72.2	1469.7

Source: Memoirs of the India Meteorological Department, Vol. XXXI, Part III.

APPENDIX

Salient Features of Important Existing Major and

Sl. No.	Name of the Project	Zone/ district	Cost/total expenditure incurred (Rs. million)	Source of supply (Name of river)	Year of completion
1	2	3	4	5	6
	Major				
Kerala					
1.	Malampuzha	Palghat	58.00	Malampuzha Tributary of Bharatapuzha	1966
	Medium				
Kerala					
2.	Kuttanad Development Scheme-I Stage	Alleppey	5.96	N.A.	1956
3.	Chalakudi Stage-I	Trichur	15.33	Chalakudi	1958
4.	Mangalam	Palghat	10.60	Cherukunupuzha	1968
5.	Peechi	Trichur	23.50	Mandi	1966
6.	Walayar	Palghat	13.17	Malampuzha & Walayar	1966
7.	Wadakan Cherry (Vazhani)	Trichur	10.76	Wadakan Cherry	1966
8.	Chalakudi Stage-II	Trichur	6.00	Chalakudi	1966
9.	Neyyar Stage-I	Trivandrum	22.60	Neyyar	1970 (anticipated)
10.	Cheerakuzhi	Trichur	9.08	Cheerakuzhi	-do-
11.	Neyyar Stage-II	Trivandrum & Kanniyakumari	17.00	Neyyar	-do-
12.	Meenakara including Chilliar (Gayathri) Stage-I & II	Palghat	22.00	N.A.	-do-
13.	Pothundi	Palghat	23.43	Ayalurpuzha	-do-
Tamil Nadu					
14.	Kodaiyar Extension & Therupprappa Weir	Kanniyakumari	23.63	Kodaiyar	1956
Gujarat					
15.	Raising Doswada Tank	Surat	0.64	N.A.	1957

Source: 1. Note volume of Irrigation Chapter on Tamil Nadu, Kerala, Mysore Maharashtra, & Gujarat—C.W. & P.C.—March-1970 (Unpublished).

12.2

Medium Projects in the West Flowing Rivers Basin

Type (Flow storage lift)	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Length of main canal & branches km.	Whether perennial, two seasonal or one seasonal	Cropping Pattern	Remarks
7	8	9	10	11	12	13	14
Storage	N.A.	44.11	38.53	64.37	One seasonal	Rice	
Flow	N.A.	N.A.	48.98	N.A.	N.A.	N.A.	
Flow	11.50	11.50	22.99	224.50	One seasonal	Rice	
Storage	4.00	3.49	6.48	42.47	One seasonal	Rice	
Storage	18.62	18.62	28.08	82.00	One seasonal	Rice	
Storage	N.A.	3.29	6.48	11.27	One seasonal	Rice	
Storage	4.65	3.56	7.13	38.6	Two seasonal	Rice & Rabi	
Flow	8.18	8.18	16.39	27.30	One seasonal	Rice	
Storage	8.77	7.69	15.38	N.A.	N.A.	N.A.	
Flow	3.24	1.62	3.24	63.00	One seasonal	Rice	
Flow	8.38	4.45	8.09	N.A.	N.A.	N.A.	
Storage	N.A.	N.A.	10.93	N.A.	N.A.	N.A.	
Storage	10.93	5.26	8.90	18.90	One seasonal	Rice	
Flow	25.90	25.90	47.53	N.A.	N.A.	N.A.	
Storage	N.A.	N.A.	0.92	N.A.	N.A.	N.A.	

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2. Replies of the State Governments of Tamil Nadu, Kerala, Mysore, Maharashtra & Gujarat to the questionnaire issued by Irrigation Commission.
3. Irrigation Statistics of India (1960-61)—C.W. & P.C.—March, 1968.

APPENDIX

Salient Features of Important Major and Medium Projects

Sl. No.	Name of the Project	Zone/ district	Description of the scheme	Time schedule of cons	
				Date of commencement	Important items of work complete
1	2	3	4	5	6
Major					
Kerala					
1.	Pamba	Quilon	79 m long barrage, 9.14 km tunnels, 149 km canals	1961	Barrage 95% canals and tunnel in progress
2.	Kuttiyadi	Kozhikode	171 m long dam, 35 m high and 249 km canal system	1962	Headworks 77% canal system 50%
3.	Kallada	Quilon	Masonry dam 335m long, 73 m high, pickup weir and 152 km main canal	1962	Excavation of dan completed, wei and canal systen just started
Tamil Nadu					
4.	Parambikulam	Coimbatore	7 reservoirs, 24 km tunnels a weir, 298 km of lined main canal	1958	4 reservoirs com pleted with can systems
5.	Chittar Pattnamkal	Kanniya-kumari	762 m & 1076 m long, 22 m & 25 m high two earth dams with inter-connected channels and certain improvement works on existing dams and canals	1963	83% of two dam completed. Can systems from 62 t 100% completed

12.3

nder Construction in the West Flowing Rivers Basin

uction	Cost					
Date of likely ompletion	Total cost (Rs. million)	Expenditure incurred up to March 1969 (Rs. million)	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Remarks
7	8	9	10	11	12	13
1974	92.05	29.30	N.A.	33.99	34.00	
1973	52.42	28.55	N.A.	31.17	51.16	
Vth Plan	144.91	9.03	107.95	105.25	105.22	
IVth Plan	500.70	388.30	N.A.	97.13	97.13	
IVth Plan	73.30	51.10	N.A.	N.A.	19.02	

Appendix

Sl. No.	Name of the Project	Zone/ district	Description of the scheme	Time schedule of cons-	
				Date of commencement	Important items of work completed
1	2	3	4	5	6
Medium					
Kerala					
6.	Pazhashi (Vallapatnam)	Cannanore	229 m long, 20.4 m high barrage, 55 km main canal and 134km branch canals	1961	About 19.5% of work completed
7.	Kanhirapuzha	Palghat	A masonry dam 221 m long and 38 m high and 69 km main canals	1961	All works are under different stages of progress.
8.	Chitturpuzha	Palghat	Remodelling of existing irrigation system including extension of canals	1963	Headworks 88% (Moolathara Regulator completed canals 43% completed
Maharashtra					
9.	Kal	Kolaba	Diversion weir 12.2 m high and 298.7 m long with two canals	1965	Headworks completed, canals in progress
Mysore					
10.	Bijjur	South Kanara	Earth dam 829 m long and 23 m high, canal 138 km long	1963	Only preliminary work

Sources: 1. Note volume of Irrigation Chapter on Tamil Nadu, Kerala, Mysore, Maharashtra and Gujarat—Central Water and Power Commission—March, 1970 (Unpublished).

2. Replies of the State Governments of Tamil Nadu, Kerala, Mysore, Maharashtra and Gujarat to the questionnaire issued by the Irrigation Commission.

12.3—*Contd.*

ruction	Cost		G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Remarks
Date of likely ompletion	Total cost (Rs. million)	Expenditure incurred up to March 1969 (Rs. million)				
7	8	9	10	11	12	13
1974	47.60	9.20	28.33	28.33	28.33	
IV Plan	39.18	8.09 (July '69)	N.A.	19.42	19.42	
1972	10.93	8.45 (July '69)	N.A.	22.50	22.50	
1971	26.00	14.18	N.A.	N.A.	14.34	
V Plan	13.01	0.22 (Mar. '68)	N.A.	N.A.	1.82	

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3. Irrigation Statistics of India (1960-61)—Central Water and Power Commission—March, 1968.

APPENDIX 12.4

New Schemes Included in the Fourth Plan Subject to Clearance by the Planning Commission in the West Flowing Rivers Basin

Sl. No.	Name of the Project	Zone/district	Source of supply (name of river)	Estimated cost (Rs. million)	Ultimate irrigation ('000 hectares)	Remarks
1	2	3	4	5	6	7
Gujarat						
1.	Damanganga Project (Multipurpose)	Dadra & Nagar Haveli	Damanganga	86.00	7.00*	*In Dadra & Nagar Haveli only. (Total 45,200 hectares)
Maharashtra						
2.	Amba Valley Project	Ratnagiri	Amba	12.50	9.98	
Kerala						
3.	Karapuzha	Calicut & Cannanore	N.A.	20.00	10.52	
4.	Chimoni Mupli	N.A.	N.A.	45.00	40.49	
5.	Kuriarkutty	Palghat	N.A.	56.00	34.82	
6.	Kakkadavu	Cannanore	N.A.	50.00	20.23	
7.	Silent Valley	Palghat	N.A.	35.00	32.40	
8.	Idikki	N.A.	N.A.	112.50	97.13	
9.	Idamalayar	N.A.	N.A.	N.A.	14.16	
10.	Bhavani Valley	N.A.	N.A.	10.00	3.24	

Source: 1. Replies of the State Governments of Tamil Nadu, Kerala, Mysore, Maharashtra and Gujarat—to the questionnaire issued by the Irrigation Commission.

2. Report of the Working Group on Irrigation and Flood Control, Fourth Five Year Plan (1969-74) and Annual Plan (1969-70) for Tamil Nadu, Kerala, Mysore, Maharashtra and Gujarat.

APPENDIX 13.1

Salient Features of Existing Major & Medium Projects in the Tapi Basin

Sl. No.	Name of the Project	Zone/ District	Cost/ Total (Expenditure incurred in Rs. million)	Source of supply (Name of river)	Year of completion	Type (Flow/ Storage/ Lift)	Ultimate Irrigation ('000 hectares)
				Maharashtra			
1.	Jamda Weir	East Khandesh	1.09	Girna	1902	Flow	3.56
2.	Chankapur dam and Thengoda weir	Nasik	2.26	Girna	1916	Flow-cum-storage	8.09
3.	Parsul Tank	-do-	0.22	Parsul	N.A.	Storage	0.76
4.	Sukhi	-do-	N.A.	Sukhi	N.A.	-do-	1.21
5.	Mahawa Tank	Jalgaon	0.14	Bori	N.A.	-do-	0.47
6.	Mosam Weir	Nasik	3.61	Mosam	1957	Flow	3.15
7.	Nalganga	Buldana	27.32	Nalganga	1969	Storage	8.74
				Gujarat			
8.	Bandhara across Ver	Surat	0.90	Ver	1959	Flow	1.38

Source (*i*) Irrigation Statistics of India (1960-61), Central Water & Power Commission.

(*ii*) Note volumes of Irrigation Chapters for Gujarat and Maharashtra State, Central Water & Power Commission (1970), Unpublished.

APPENDIX

Salient Features of Major and Medium Projects Under

				Cost	
Sl. No.	Name of the project	Zone/ District	Description of the Scheme	Total cost (Rs. million)	Expenditure incurred (Rs. million)
1	2	3	4	5	6
			Maharashtra		
1.	Girna	Dhulia	Construction of an earthen dam 963 m long, 55 m high across the river Girna, near village Banzaan, pick-up weirs at Jamda and Dahigaon and canal system	146.00	145.14 (Upto Mar. '69)
2.	Katepurna	Akola	Construction of an earthen dam 28 m long across river Katepurna near village Vastapur and a canal 18 m long taking off from a pick-up weir near village Khembora, 16.1 km downstream of the dam	41.27	33.47 (Mar. '69)
3.	Malangaon	Dhulia	Construction of a dam across river Kan near village Malangaon and a canal 31 km long	7.42	5.94 (Mar. '70)
4.	Karwand	Dhulia	Construction of a dam across river Arunavati, a tributary of Tapi, a pick-up weir downstream of village Karwand and a right bank canal 13 km long	17.40	15.15 (Mar. '70)
5.	Morna	Akola	Construction of an earthen dam across the river Girna, a pick-up weir lower down near village Rajanda and a canal on the left bank	17.30	11.86 (Mar. '69)
6.	Gyanganga	Buldana	Construction of an earthen dam across river Gyanganga near village Gerumatergaon, a pick-up weir near village Tandulwadi & canal system	19.00	12.52 (Mar. '70)

13.2

Construction in the Tapi Basin

Time schedule of construction					
Date of commencement	Important items of work completed	Date of likely completion	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)
7	8	9	10	11	12
1956	The project is in an advanced stage of construction	IV Plan	106.01	79.47	57.21
1961	The project is in an advanced stage of construction	1970	30.00	16.19	8.35
1964	Headwork completed and canal system 90% completed	1970	N.A.	N.A.	2.26
1964	The project is nearing completion	1970	N.A.	N.A.	4.53
1964	Pick up weir completed. Work on the earth dam and the canal system is in progress	1970	N.A.	N.A.	5.26
1964	Nearly 85% of work on headworks and canal system has been completed	1971	N.A.	N.A.	4.37

Appendix

1	2	3	4	5	6
7.	Chankapur Dam	Nasik	Strengthening and raising of the existing Chankapur dam and extension of the existing canals	22.00	6.05 (Mar. '70)
8.	Panzara	Dhulia	Construction of a dam across river Panjhra and canal system	18.31	2.90 (Mar. '70)
9.	Nirguna	Akola	Construction of an earthen dam 2049 m long and 25 m high across river Nirguna & a right bank canal 200 km long	18.98	1.79 (Mar. '70)
10.	Manyad	Jalgaon	Construction of an earthen dam across river Manyad and a right bank canal 23 km long	17.50	0.68 (Mar. '69)
11.	Kanholi	Dhulia	Construction of an earthen dam across river Kanholi near village Nandala and a right bank canal 14 km long	4.14	1.19 (Mar. '70)
			Gujarat		
12.	Kakrapar	Surat	Construction of a 621 m long and 14 m high pick-up weir across river Tapi near Kakrapar with two canals one on either bank	180.50	159.49 (Sept. '70)
13.	Ukai	Surat	Construction of a composite dam 4927 m long, 69 m high across river Tapi near village Ukai and canal system 954 km long	104.40	571.54 (Oct. '70)

Source (*i*) Irrigation Statistics of India (1960-61), Central Water & Power Commission.

(*ii*) Note Volumes of Irrigation Chapters for Gujarat and Maharashtra States, Central Water & Power Commission (1970)—Unpublished.

13.2—*Contd.*

7	8	9	10	11	12
1967	Headworks 19% completed and canal system 48% completed	IV Plan	N.A.	7.57	12.04
1967	Headworks 18% completed	1973	N.A.	N.A.	7.77
1968	The project is in the initial stages of construction & up to March 1970 about 15% of the headworks had been completed	1973	11.57	8.51	8.75
1969	Work not yet physically started	1972	7.69	6.24	6.86
1969	Headworks 16% completed	1972	N.A.	N.A.	1.05
1949	The project is in an advanced stage of construction	IV Plan	345.47	227.71	227.53
1960	Earth dam 77% completed. In masonry dam, masonry work 78% completed, concreting 63% completed. Regulator is almost complete	V Plan	217.89	191.42	152.40

APPENDIX 13.3

New Schemes Included in the Fourth Five Year Plan Subject to Clearance by the Planning Commission

Sl. No.	Name of the Project	Name of State	Estimated cost (Rs. million)	Ultimate Irrigation ('000 hectares)
1.	Chandora	Madhya Pradesh	17.45	3.10
2.	Upper Tapi	Maharashtra	120.90	55.25
3.	Haranbari	-do-	17.90	9.72
4.	Aner	-do-	26.68	N.A.

Note: There is no new scheme to be taken up in the basin during the Fourth Five Year Plan in Gujarat State.

Source: Report of the Working Group on Irrigation & Flood Control, Fourth Five-Year Plan (1969-74) and Annual Plan (1969-70) for Gujarat, Madhya Pradesh and Maharashtra.

APPENDIX 13.4

New Major and Medium Projects Proposed by the State Governments in the Tapi Basin

Sl. No.	Name of the Project	District	Remarks
Madhya Pradesh			
1.	Nishana	Betul	
2.	Daura	Betul and East Nimar	
3.	Nawtha	East Nimar	
4.	Naichondi	-do-	
5.	Abhora	-do-	
6.	Utaoli	-do-	
7.	Siwal	-do-	
Maharashtra			
8.	Popat kheda	Akola	
9.	Vishwamittri	-do-	
10.	Nirgana	-do-	
11.	Sipna	-do-	
12.	Pimpalgaon	-do-	
13.	Moghari	-do-	
14.	Ghonga	-do-	
15.	Mathoda	-do-	
16.	Kusum	-do-	
17.	Kavat	-do-	
18.	Sakhi	-do-	
19.	Shanpur	Amaravati	
20.	Morgarh	-do-	
21.	Wan (Salwan)	-do-	
22.	Kharja Gutighat	-do-	
23.	Londi	Buldana	
24.	Pandharwal	-do-	
25.	Mohadi	-do-	
26.	Bidi	-do-	
27.	Mas	-do-	
28.	Torna	-do-	
29.	Mun	-do-	
30.	Pimpalner	Dhulia	
31.	Gomai (Mohida)	-do-	

Appendix 13.4—*Contd.*

Sl. No.	Name of the Project	District	Remarks
32.	Amrala Weir	-do-	
33.	Mukti	-do-	
34.	Kathore	-do-	
35.	Mahasarda Weir	-do-	
36.	Mor	Jalgaon	
37.	Suki	-do-	
38.	Tamaswadi	-do-	
39.	Waghor	-do-	
40.	Kelzar	Nasik	

Note: Information for Gujarat State is not available.

APPENDIX 14.1

Runoff Series at Garudeshwar (Navagam)

Year	Runoff at Garudeshwar (Navagam) (M.cu.m.)	Year	Runoff at Garudeshwar (Navagam) (M.cu.m.)
1915	48,611	1939	41,038
1916	55,124	1940	47,094
1917	61,007	1941	19,674
1918	17,355	1942	56,691
1919	63,018	1943	49,364
1920	25,262	1944	75,045
1921	35,549	1945	46,181
1922	34,143	1946	54,766
1923	52,324	1947	50,499
1924	41,395	1948	53,706
1925	31,330	1949	42,703
1926	54,791	1950	37,979
1927	36,536	1951	22,597
1928	38,139	1952	23,572
1929	34,648	1953	29,566
1930	42,148	1954	42,555
1931	56,617	1955	52,953
1932	43,122	1956	47,625
1933	58,627	1957	27,938
1934	53,989	1958	41,766
1935	36,166	1959	55,309
1936	48,476	1960	34,722
1937	51,078	1961	71,061
1938	50,610	1962	33,699

Average=44,331 m.cu.m.

Source: Report of the Narmada Water Resources Development Committee, September, 1965.

APPENDIX

Salient Features of Existing Major and

Sl. No.	Name of the Project	Zone/ District	Cost/Total expenditure incurred (Rs. million)	Source of supply (Name of river)	Year of completion
1	2	3	4	5	6
Madhya Pradesh					
1.	Bohribund	Jabalpur	1.30	Bhutanala	1929
2.	Sampana	Betul	4.88	Tributary to Tawa	1956
3.	Dukhrikheda	Hoshangabad	4.38	Ghoguarnalla	1961
4.	Dhuandhar	Mandla	4.59	Dhuandharnalla	1966
Gujarat					
5.	Bandhara across Hiran	Baroda	1.73	Hiran	1965

Source: (*i*) Irrigation Statistics of India (1960-61), Central Water & Power Commission.

14.2

Medium Projects in the Narmada Basin

Type (Flow/ Storage/ Lift)	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Length of main canal & branches (km.)	Whether perennial, two seasonal or one seasonal	Cropping pattern
7	8	9	10	11	12	13
Storage	18.62	6.41	2.71	N.A.	Two seasonal	Rice, Wheat
-do-	8.85	7.50	2.20	22.52	Perennial	Surgacane, Rice, Maize & Barley
-do-	6.12	5.75	2.67	56.62	One seasonal	Wheat
-do-	1.46	1.41	1.33	12.80	-do-	Rice
Flow	4.84	3.88	2.08	54.72	N.A.	N.A.

(*ii*) Note volumes of Irrigation Chapters for Madhya Pradesh and Gujarat (1970), Central Water & Power Commission (Unpublished).

(*iii*) Replies of Madhya Pradesh and Gujarat States to the Questionnaire issued by the Irrigation Commission.

APPENDIX

Salient Features of Major and Medium Projects

Sl. No.	Name of the Project	Zone/District	Description of the scheme	Total cost (Rs. million)	Expenditure incurred (Rs. million)
1	2	3	4	5	6
Madhya Pradesh					
1.	Satak (Borad)	West Nimar	Construction of two earthen dams, one near Bamundi and the other near Segwal and a pick up weir on Borad river near Jarwai	14.16	9.27 (upto Mar. '69)
2.	Chandrakesar	Dewas	Construction of an earthen dam 2,438 m. long across river Chandrakesar and a left bank canal	27.00	8.28 (upto Mar. '70)
3.	Barna	Raisen	Construction of a masonry dam 432 m. long across river Barna and 38 km. long main canal	70.00	17.56 (upto Mar. '70)
4.	Tawa	Hoshangabad	Construction of an earth-cum-masonry dam with maximum height of 57.95 m. across river Tawa and two canals one on either side	401.90	115.64 (upto June '70)
Gujarat					
5.	Narmada (Broach)	Broach	Construction of a dam 2012 m. long with maximum height of 69.2 m. above foundation across river Narmada with 143.2 km. of main canal and branches	1097.00 (Scope under revision)	49.37 (upto Mar. '70)

Source: (i) Note Volumes of irrigation chapters for Madhya Pradesh and Gujarat States, 1970, Central Water & Power Commission (Unpublished).

14.3

Under Construction in the Narmada Basin

Time schedule of construction					
Date of commencement	Important items of work completed	Date of likely completion	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)
7	8	9	10	11	12
1956	Construction of Satak tank is completed. Work on Segwal tank is in progress	1970-71	4.45	3.84	5.06
1958-59	Construction of head-works is in progress. Work on canal system also has just started	IV Plan	13.77	11.08	4.86
1960	Excavation of masonry dam & approach channel is in progress. Canal system is in the initial stages of construction	,,	101.21	87.41	60.30
1962	Excavation including trenching & embankment in the case of earth dam and excavation, concreting & masonry works in the case of masonry dam are in progress. Left bank canal and distribution system are in the early stage of construction	,,	562.91	401.85	331.85
1959	Preliminary works are in progress	V Plan	538.23	445.65	403.69

(ii) Replies of Madhya Pradesh and Gujarat States to the Questionnaires issued by the Irrigation Commission.

APPENDIX 14.4

New Schemes Included in the Fourth Five Year Plan Subject to Clearance by the Planning Commission

Sl. No.	Name of the project	Name of the State	Estimated cost (Rs. million)	Ultimate irrigation ('000 hectares)
1.	Bargi	Madhya Pradesh	640.00	267.00
2.	Bichhia	„	5.82	2.43
3.	Umarnala	„	6.45	3.24

Note: There are no new schemes to be taken up in the basin during the Fourth Plan in Maharashtra and Gujarat States.

APPENDIX 14.5

Salient Features of New Major & Medium Projects Proposed by the State Governments in the Narmada Basin

Sl. No.	Name of the project	District	Ultimate irrigation ('000 hectares)	Remarks
1	2	3	4	5
1.	Upper Narmada	Shadol and Mandla	52.61	
2.	Suini	Mandla & Bilaspur	8.09	
3.	Upper Burnher	Mandla	68.80*	
4.	Surpan	Mandla	8.09	
5.	Rosra	Mandla	161.87	(Includes 141.64 thousand hectares under Bargi canal).
6.	Basania	Mandla		
7.	Barnher	Mandla		
8.	Halon	Balaghat	16.19	
9.	Kanhar	Balaghat	1.82	
10.	Sitarewa	Narasimhapur	32.37*	From Dudhi pick-up weir.
11.	Kolaraschan	Sehore	40.47	
12.	Machna	Betul	2.02	
13.	Omkareshwar (Barwaha)	West Nimar	138.81	
14.	Choral	Indore	4.25	
15.	Man	Dhar	19.02	
16.	Chinki	Jabalpur	60.70	
17.	Narmadasagar (Punasa)	East Nimar	242.81	
18.	Bilgaon	Mandla	3.24	
19.	Turar	,,	4.05	
20.	Kanwa	,,	1.62	
21.	Bhajotola	,,	1.62	

*Irrigation in Mahanadi basin.

Sl. No.	Name of the project	District	Ultimate irrigation ('000 hectares)	Remarks
22.	Matiari	Mandla	4.86	
23.	Kamta	,,	10.52	
24.	Banjira	,,	8.50	
25.	Boira	,,	6.07	
26.	Mohatra	,,	8.50	
27.	Gurdanala	Seoni	1.62	
28.	Lahsarbandh	Jabalpur	6.47	
29.	Bhagelanala	,,	1.62	
30.	Maurinala	Mandla	1.62	
31.	Labheranadi	Jabalpur	3.64	
32.	Papatpur	,,	1.62	
33.	Dallanala	,,	1.01	
34.	Mehgaontola	,,	2.43	
35.	Kair Dam	,,	1.62	

Appendix 14.5—*Contd.*

Sl. No.	Name of the project	District	Ultimate irrigation ('000 hectares)	Remarks
1	2	3	4	5
36.	Narrai	,,	2.47	
37.	Upper Pariat	,,	4.05	
38.	Bamhni	Narasimhapur	1.62	
39.	Damoh	Balaghat	1.62	
40.	Thana	Hoshangabad	2.23	
41.	Nayagaon	,,	2.83	
42.	Sukinala	Betul	1.62	
43.	Denwanala	,,	2.02	
44.	Lonia	,,	6.47	
45.	Limkheda	East Nimar	1.62	
46.	Itwa	,,	4.86	
47.	Kaveri	,,	4.05	
48.	Ajnal	East Nimar	2.43	
49.	Khurpatni	Raisen	1.62	
50.	Dongaria	,,	4.05	
51.	Tendoni weir	,,	4.05	
52.	Moga	,,	2.02	
53.	Kachwara	,,	3.24	
54.	Datuni	Dewas	6.07	
55.	Bagninadi	,,	1.62	
56.	Ambaknala	West Nimar	2.02	
57.	Chitanala	,,	4.05	
58.	Undri	,,	3.64	
59.	Khedi	,,	2.02	
60.	Padlia Buzrug	,,	1.62	
61.	Kunda weir	,,	1.62	
62.	Kundi	,,	9.51	
63.	Kharkhnala	,,	8.74	
64.	Satsoi	,,	7.61	
65.	Veda	,,	12.14	
66.	Odhali	,,	1.62	
67.	Belgaon	,,	2.02	
68.	Kheril	Dhar	2.02	
69.	Mandiwadi	,,	4.05	

Note: Information for Gujarat and Maharashtra States is not available.

Source: Irrigation and Power Potential of Madhya Pradesh rivers, P.W.D., Government of Madhya Pradesh (1963).

APPENDIX 15.1

Monthly and Annual Normals of Rainfall in the Mahi Basin

Sl. No.	District	Monthly rainfall (mm.)												Annual rainfall mm.
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	
Madhya Pradesh														
1.	Dhar	4.0	0.9	1.1	1.4	9.8	127.4	255.5	204.0	176.1	31.3	17.9	3.7	833.1
2.	Jhabua	4.5	1.9	1.5	0.7	9.1	116.3	283.3	211.5	162.3	25.5	9.5	1.9	828.0
3.	Ratlam	6.4	3.0	2.3	1.2	8.7	117.4	298.1	269.6	160.4	16.9	8.7	3.2	895.9
Rajasthan														
4.	Banswara	3.2	1.9	1.4	0.8	4.2	109.7	322.2	293.5	161.3	17.6	5.7	0.9	922.4
5.	Chittorgarh	6.0	2.3	2.3	1.5	5.5	85.5	294.9	309.1	125.0	9.9	6.3	3.8	852.1
6.	Dungarpur	2.1	1.9	1.3	1.1	7.2	98.9	286.7	233.2	113.0	11.0	4.3	1.0	761.7
7.	Udaipur	7.7	3.3	3.0	1.8	8.1	66.3	219.5	194.0	104.3	9.8	4.8	1.9	624.5
Gujarat														
8.	Baroda	2.0	2.5	0.8	3.2	4.8	123.3	389.6	233.8	170.1	28.2	9.1	1.4	968.8
9.	Broach	3.2	1.6	0.8	3.5	4.2	137.6	368.4	209.5	176.5	32.5	10.6	1.3	949.7
10.	Kaira	1.6	2.0	1.9	3.0	5.6	95.9	344.3	207.1	135.9	12.9	4.2	0.7	815.1
11.	Panchmahals	2.9	2.0	1.7	1.7	8.2	123.2	377.5	266.7	175.1	20.3	7.3	1.4	988.0

Source: Monthly and Annual Normals of Rainfall and of Rainy days (based on records from 1901 to 1950), India Meteorological Department.

APPENDIX

Salient Features of Existing Major and

Sl. No.	Name of the Project	Zone/ District	Cost/ Total expenditure incurred (Rs. million)	Source of supply (Name of river)	Year of completion	Type (Flow/ storage/ lift)
1	2	3	4	5	6	7
Madhya Pradesh						
1.	Shivgarh Bhedli Tank	Ratlam	1.834	Local nalla	1957	Storage
Rajasthan						
2.	Jaisamand	Udaipur	6.000	Gomti	N.A.	Storage
3.	Kantri	Dungarpur	0.136	N.A.	1956	Storage
4.	Lodisar-ka-Naka	Dungarpur	1.900	Moran	1957	Storage
5.	Surwania	Banswara	2.000	Surwania	1962	Storage
6.	Gadola	Chittorgarh	0.800	N.A.	1964	Storage
7.	Jakham (Part I)	Udaipur	2.700	Jakham	1964	Flow
Gujarat						
8.	Karad	Panchmahals	9.988	Karad	1964	Storage
9.	Patadungri	Panchmahals	8.225	Khan	1966	Storage

Source: (i) Irrigation Statistics of India (1960-61), Central Water & Power Commission.

(ii) Note volumes of Irrigation Chapter for Madhya Pradesh, Rajasthan and Gujarat, Central Water & Power Commission (1970)—Unpublished

(iii) Replies of Madhya Pradesh, Rajasthan and Gujarat to the questionnaire issued by the Irrigation Commission.

15.2

Medium Project Mahi Basin

G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Length of main canal and branches Km.	Whether perennial, two seasonal or one seasonal	Cropping pattern	Remarks
8	9	10	11	12	13	14
0.727	0.497	0.891	9.00	Perennial	Sugarcane, Barley	
6.313	5.058	4.050	57.90	N.A.	N.A.	
N.A.	N.A.	0.160	N.A.	N.A.	N.A.	
1.618	1.173	1.011	72.00	Two seasonal	Mostly wheat	
2.566	2.332	1.839	23.00	Two seasonal	Mostly wheat	
N.A.	N.A.	0.530	N.A.	N.A.	N.A.	
0.688	0.526	0.485	N.A.	Two seasonal	Mostly wheat	
10.000	7.480	4.480	N.A.	N.A.	N.A.	
6.231	5.061	4.827	26.00	N.A.	N.A.	

APPENDIX

Salient Features of Major and Medium Projects

Sl. No.	Name of the Project	Zone/ District	Description of the scheme	Time schedule of cons-	
				Date of commencement	Important items of work completed
1	2	3	4	5	6
Madhya Pradesh					
1.	Pampawati	Jhabua	Construction of an earthen dam across river Pampavati and a canal system	1967	Headworks 42% completed. Canal works yet to be taken up
Gujarat					
2.	Mahi Right Bank Canal (Mahi Stage I)	Kaira	Construction of a masonry pick-up weir, 796 m long, 20.6 m high across the river Mahi near village Wanakbori and a canal system on the right bank	1948	Headwork completed. Work on the construction of the canal systemt i in progress
3.	Kadana (Mahi Stage II)	Panchmahals	Construction of an earth cum masonry dam 2,225 m. long, 58.2 m. high across the river Mahi at Kadana village, about 70.8 km upstream of the Wanakbori weir and a canal taking off on the left bank for irrigating an area of 16,566 hectares. In addition, supplies to the area commanded by the	1956	Work is in he initial stages of construction

15.3

Under Construction in the Mahi Basin

truction	Cost					
Date of likely completion	Total cost (Rs. million)	Expenditure incurred (Rs. million)	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Remarks
7	8	9	10	11	12	13
IV Plan	5.853	2.151 (Up to Mar. '70)	N.A.	N.A.	1.093	
IV Plan	245.68	166.71 (Up to Dec. '69)	315.650	263.042	186.162	
IV Plan	210.014	24.229 (Up to Dec. '69)	315.650	263.042	270.000*	*Including irrigation under the Mahi Project Stage I

Appendix

1	2	3	4	5	6
			Wanakbori weir will be firmed up and irrigation will be increased from 186,162 hectares to 270,000 hectares		

Source: (i) Note volumes of Irrigation Chapter for Madhya Pradesh and Gujarat, Central Water & Power Commission (1970)—Unpublished.

(ii) India Irrigation & Power Projects (Five Year Plans), Central Water & Power Commission (April, 1970).

15.3—*Contd.*

7	8	9	10	11	12	13

(iii) Replies of Madhya Pradesh and Gujarat to the questionnaire issued by the Irrigation Commission.

APPENDIX 15.4

New Schemes Included in the Fourth Plan Subject to Clearance by the Planning Commission

Sl. No.	Name of the Project	Zone/ District	Source of supply (Name of river)	Estimated cost (Rs. million)	Ultimate irrigation ('000 hectares)	Remarks
Rajasthan						
1.	Mahi (Banswara) Project	Banswara	Mahi	49.50	30.75	
2.	Jakham (Part II)	Udaipur	Jakham	30.00	11.52	
Gujarat						
3.	Panam	Panchmahals	Panam	101.119	21.87	

Source: (*i*) Report of the Working Group on Irrigation and Flood Control, Fourth Five Year Plan (1969-74) and Annual Plan (1969-70) for Madhya Pradesh, Rajasthan and Gujarat.

(*ii*) Replies of Gujarat to the questionnaire issued by the Irrigation Commission.

APPENDIX 15.5

Details of New Major and Medium Projects Proposed in Mahi Basin by Various States

Sl. No.	Name of the Project	Zone/ District	Source of supply (Name of river)	Estimated cost (Rs. million)	Ultimate irrigation ('000 hectares)	Remarks
Rajasthan						
1.	Anas Multipurpose project	Banaswara	Anas	200.00	121.41	
2.	Baneshwar ,, ,,	Banaswara	Mahi	350.00	202.34	
3.	Daia	Udaipur	Daia	6.00	1.24	
4.	Somkamla Amba	Dungarpur	Som	20.00	7.20	
Gujarat						
5.	Kadana Right Bank High Level Canal	Panchmahals	Mahi	N.A.	N.A.	

Source: (*i*) Report of the Kadana Reservoir Project (1969), Government of Gujarat.
(*ii*) Replies of Rajasthan to the questionnaire issued by the Irrigation Commission.

APPENDIX 16.1

Salient Features of Existing Major and Medium Projects in Sabarmati Basin

Sl. No.	Name of the Project	Zone/ District	Cost/ Total expenditure incurred in Rs. million	Source of supply (Name of river)	Year of completion	Type (Flow/ storage/ lift)	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Length of main canal and branches (Km.)	Whether perennial, two seasonal or one seasonal	Cropping pattern	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Gujarat													
1.	Hathmati Project	Sabarkantha	1.374	Hathmati	1874	Flow	11.534	N.A.	4.047	15.10	N.A.	N.A.	
2.	Karicut Canal Project	Sabarkantha		Khari	1884	Flow			2.833				
3.	Bokh	N.A.	N.A.	N..A	1909-10	Storage	N.A.	N.A.	0.809	N.A.	N.A.	N.A.	
4.	Meshwa Canal System (Raska Weir)	Kaira	5.4	Meshwa	1950	Flow	8.0	N.A.	7.284	45.70	N.A.	N.A.	
5.	Ahmadabad Water Supply	Ahmedabad	N.A.	Sabarmati	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
6.	Nani Fatewadi Canal System	Ahmedabad	1.098	Sabarmati	1951	Flow	7.6	6.08	6.08	N.A.	N.A.	N.A.	

7. Moti Fatewadi Canal System	Ahmedabad	7.23	Sabarmati	1966-67	Flow	128.0	28.80	12.950	53.91	N..A	N.A.
8. Hathmati Reservoir	Sabarkantha	54.46	Hathmati	1968-69	Storage	N.A.	47.49	37.604	191.2	N.A.	N.A.
9. Harnav	Sabarkantha	5.24	Harnav	1969	Flow	4.0	3.345	2.670	12.87	N.A.	N.A.
10. Karol	Sabarkantha	1.20	Bokh	1969	Storage	N.A.	N.A.	1.210	N.A.	N.A.	N.A.
11. Shamlaji (Meshwa Reservoir)	Sabarkantha	31.43	Meshwa	1969	Storage	N.A.	33.92	23.900	41.03	N.A.	N.A.

Source: (i) Irrigation Statistics of India (1960-61), Central Water & Power Commission.
(ii) Report on Sabarmati Basin for assessment of surface water resources, CW&PC (September, 1969).
(iii) Note Volume of Irrigation Chapter for Gujarat (March, 1970), C.W. & P.C. (Unpublished).
(iv) Replies of the Government of Gujarat to the questionnaire issued by the Irrigation Commission.

APPENDIX 16.2

Salient Features of Major and Medium Projects Under Construction in the Sabarmati Basin

Sl. No.	Name of the Project	Zone/ District	Description of the Scheme	Time schedule of construction			Cost		G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ulti-mare irriga-tion ('000 hectares)	Remarks
				Date of com-mence-ment	Important items of works completed	Date of likely comple-tion	Total cost (Rs. million)	Expenditure incurred (Rs. million)				
1	2	3	4	5	6	7	8	9	10	11	12	13
Rajasthan												
1.	Sei Diversion Scheme	Udaipur	Construction of a 24.23 m high dam across river Sei, a tributary of the Sabarmati and a 5,784 m. long tunnel for diverting the water to the Jawai river	1968	The work is in the initial stages of construction	Fourth Plan	15.00	0.342 (up to Mar. '69)	N.A.	N.A.	8.920	

Source: Note Volume of Irrigation Chapter for Rajasthan (March, 1970)—C.W. & P.C. (Unpublished)

APPENDIX 16.3

New Schemes Included in the Fourth Five Year Plan Subject to Clearance by the Planning Commission

Sl. No.	Name of the Project	Zone/ District	Estimated cost (Rupees million)	Ultimate irrigation ('000 hectares)	Remarks
1	2	3	4	5	6
Gujarat					
1.	Sabarmati Reservoir Project	Mehsana	165.5	39.66	The project will also firm up the existing irrigation under Fatewadi Irrigation Scheme and provide water supply to Gandhinagar township

Source: (*i*) Report of the Working Group on Irrigation and Flood Control, Fourth Five Year Plan (1969-74) and Annual Plan (1969-70) for Gujarat State.

(*ii*) Replies of Gujarat to the Questionnaire issued by the Irrigation Commission.

APPENDIX 17.1

Monthly and Annual Normals of Rainfall in the Basin of the Luni and Other Rivers of Saurashtra and Kutch

Sl. No.	State/District	Month-wise Normal Rainfall in mm												Annual Normal Rainfall in mm
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Rajasthan													
1.	Ganganagar	9.7	9.8	6.8	5.3	5.5	27.4	77.4	73.1	31.4	3.2	0.3	3.8	253.7
2.	Bikaner	3.9	6.1	4.1	4.2	10.0	25.1	78.0	89.5	33.0	5.9	0.4	3.5	263.7
3.	Churu	8.6	6.6	5.3	4.2	9.9	34.8	101.0	95.2	49.4	5.2	1.2	4.1	325.5
4.	Jhunjhunu	11.1	9.4	8.3	5.4	13.5	48.4	141.3	125.7	65.8	8.5	1.9	5.2	444.5
5.	Sikar	14.1	7.2	7.3	3.9	10.9	37.3	160.9	137.5	74.4	5.8	1.7	5.1	466.1
6.	Nagaur	6.2	6.0	4.9	3.4	12.1	37.3	127.6	127.9	52.1	5.6	1.3	4.2	388.6
7.	Jaipur	11.5	9.0	5.6	3.5	10.0	50.3	180.0	180.7	81.8	8.8	1.8	5.2	548.2
8.	Ajmer	5.5	5.0	4.3	2.7	10.3	50.9	172.8	181.3	77.6	11.1	2.7	3.1	527.3
9.	Udaipur	7.7	3.3	3.0	1.8	8.1	66.3	219.5	194.0	104.3	9.8	4.8	1.9	624.5
10.	Jodhpur	4.4	5.0	3.1	2.6	8.4	28.9	97.3	122.6	39.8	4.0	1.0	1.6	318.7
11.	Jalore	2.9	4.5	1.9	1.6	5.5	39.5	151.7	155.2	50.3	6.2	0.8	1.5	421.6
12.	Pali	3.9	4.9	2.5	2.2	9.8	43.3	151.5	190.1	73.7	5.6	1.3	1.6	490.4
13.	Sirohi	4.2	5.2	1.7	2.5	12.0	57.7	238.1	226.3	76.3	9.2	3.0	2.2	638.4
14.	Jaisalmer	2.2	4.2	1.9	1.3	3.2	10.1	54.8	72.2	12.5	0.5	0.5	0.6	164.0
15.	Barmer	2.8	3.6	2.5	1.6	6.6	19.4	87.3	113.1	33.7	3.6	0.6	1.1	275.9

Gujarat													
16. Banaskantha	2.6	4.2	1.7	1.1	8.5	53.0	248.8	211.8	82.0	8.6	2.5	1.7	626.5
17. Mehsana	2.0	2.0	1.7	1.1	5.7	62.9	272.9	166.9	82.7	5.8	3.4	1.9	609.0
18. Ahmedabad	1.5	1.4	1.4	1.9	9.5	78.7	266.0	153.3	94.4	12.1	4.7	0.9	625.8
19. Surendranagar	1.7	1.3	1.4	1.6	6.4	73.6	217.8	114.1	73.5	9.7	4.7	1.0	506.8
20. Bhavnagar	2.2	1.6	1.6	7.0	8.9	99.5	223.6	116.5	100.4	24.5	6.2	1.3	593.3
21. Amreli	1.7	2.1	0.9	7.4	5.5	87.1	193.1	95.6	78.9	20.2	6.7	1.7	500.9
22. Junagadh	1.6	2.3	1.8	2.0	6.6	119.8	272.2	118.3	78.0	15.7	3.0	1.9	623.2
23. Rajkot	1.2	2.0	1.7	2.7	9.1	91.1	252.2	125.6	81.8	16.9	4.0	1.4	589.7
24. Jamnagar	1.1	2.1	1.7	0.5	5.6	61.9	228.3	101.3	57.0	8.1	2.1	1.4	471.1
25. Kutch	1.8	3.5	0.9	0.7	4.3	36.8	150.9	83.0	32.5	4.1	2.0	1.7	322.2

Source: Memoirs of the India Meteorological Department, Vol. XXXI, Part III.

APPENDIX

Salient Features of Existing Major and Medium Projects in the Basin

Sl. No.	Name of the Project	Zone/ District	Cost/ Total Expenditure incurred Rs. million	Source of Supply (name of river)	Year of completion
1	2	3	4	5	6
Rajasthan					
1.	Jawai	Pali	25.00	Jawai	1951
2.	Raising of Hemawas	„	0.46	N.A.	1956
3.	Bankli	„	0.98	N.A.	1956
4.	Bhula	Sirohi	0.36	N.A.	1956
5.	Ora	„	1.70	Khari, tributary of the Sukri	1957
6.	Girinanda	Pali	0.90	N.A.	1958
7.	West Banas	Sirohi	6.50	Banas	1968
Gujarat					
8.	Vijayasagar				
9.	Bhimdad	Bhavnagar	2.26	Madhu (Khari)	1953
10.	Surajwadi	Amreli	3.11	Surajwadi	1953
11.	Kankavati	Kutch	1.65	Kankavati	1953
12.	Brahmani	Surendranagar	9.09	Brahmani	1954
13.	Sanandra	Kutch	1.16	Kali	1955
14.	Sasoi	Jamnagar	8.68	Sasoi	1955
15.	Puna	„	2.02	Puna	1956

17.2

of the Luni and Other Rivers of Saurashtra and Kutch

Type (Flow/ Storage/ Lift)	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate Irrigation ('000 hectares)	Length of main canal and branches, km.	Whether perennial, two-seasonal or one-seasonal	Cropping Pattern
7	8	9	10	11	12	13
Rajasthan						
Storage	44.00	35.20	7.69	211	One seasonal	Wheat
Storage	N.A.	N.A.	0.73	N.A.	N.A.	
Storage	N.A.	N.A.	1.70	N.A.	N.A.	N.A.
Storage	N.A.	N.A.	0.40	N.A.	N.A.	N.A.
Storage	7.36	4.94	2.27	34	One seasonal	Wheat
Storage	N.A.	N.A.	0.40	N.A.	N.A.	N.A.
Storage	N.A.	6.76	4.47	60	One seasonal	Wheat
Gujarat						
N.A.						
Storage	2.80	2.00	1.15	35	Two seasonal	Kharif and Rabi crops
Storage	3.46	1.73	1.04	35	Perennial	Sugarcane, Garden & Orchards, Rice, Maize, Millets, Wheat & Gram
Storage	7.28	5.59	1.56	6	Two seasonal	Millets, Wheat, Barley and other Kharif & Rabi crops
Storage	28.28	21.82	10.93	117	Perennial	Garden & Orchards, Rice, Maize, Millets, Fibre crops, Wheat
Storage	3.76	3.02	0.67	13	Two seasonal	Millets, other Kharif crops, Wheat, Barley and other Rabi crops
Storage	7.53	4.26	3.06	60	Perennial	Sugarcane, Garden & Orchard, Rice, Maize, Wheat, Gram, other Kharif and Rabi crops
Storage	1.21	1.02	1.01	19	Perennial	Sugarcane, Garden & Orchards, Rice, Millets, Wheat and Gram

Appendix

1	2	3	4	5	6
16.	Kaila	Kutch	2.79	Kaila	1956
17.	Gondli	Rajkot	2.15	Gondali	1956
18.	Malan	Bhavnagar	4.19	Malan	1956
19.	Gajod	Kutch	1.26	Nagmati	1957
20.	Manjiasar	Rajkot	5.38	Satali	1958
21.	Rawal	Junagadh	1.10	Rawal	1960
22.	Machhu	Rajkot	15.83	Machhu	1961
23.	Ozat	Junagadh	5.62	Ozat	1962
24.	Rangoli	Bhavnagar	6.63	Rangoli	1962
25.	Ghee	Jamnagar	2.28	Ghee	1962
26.	Machhundri	Junagadh	2.30	Machhundri	1962
27.	Sakroli	,,	2.42	Sakroli	1963
28.	Bhogavo-I	Surendranagar	6.67	Bhogavo	1964
29.	Demi	Rajkot	5.30	Demi	1964
30.	Shetrunji (Palitana)	Bhavnagar	69.60	Shetrunji	1965
31.	Fulzar	Jamangar	4.35	Fulzar	1965
32.	Limbdi Bhogavo	Surendranagar	5.81	Bhogavo	1965
33.	Moj	Rajkot	9.65	Moj	1966

17.2—*Contd.*

7	8	9	10	11	12	13
Storage	4.45	3.24	0.87	4	Two seasonal	Millets, Wheat, Barley and other Kharif and Rabi crops
Storage	4.04	1.41	0.93	10	N.A.	N.A.
Storage	4.00	3.20	2.33	31	N.A.	N.A.
Storage	5.30	4.23	1.15	9	Perennial	Sugarcane, Millets, Fibre crops, wheat, Barley, other Kharif and Rabi crops
Storage	5.46	3.48	1.34	47	N.A.	N.A.
Flow	4.05	3.24	0.45	24	N.A.	N.A.
Storage	18.00	10.26	6.76	130	N.A.	N.A.
Flow	8.09	6.07	2.39	113	N.A.	N.A.
Storage	16.40	10.00	3.50	80	Perennial	Sugarcane, Garden & Orchards, Rice, Maize, Millets, Fibre Crops, Wheat, Gram
Storage	2.53	2.53	0.83	23	Perennial	Sugarcane, Garden & Orchards, Rice, Millets, Wheat and Gram
Flow	3.58	3.16	0.45	17	N.A.	N.A.
Storage	2.11	2.11	1.22	N.A.	N.A.	N.A.
Storage	4.04	3.23	1.54	18	Two seasonal	Rice, other Kharif crops, Wheat and other Rabi crops
Storage	4.86	3.11	1.58	N.A.	N.A.	N.A.
Storage	76.89	57.06	34.80	154	Perennial	Sugarcane, Garden & Orchards, Rice, Maize and other Kharif and Rabi Crops
Storage	3.40	2.16	1.21	N.A.	N.A.	N.A.
Storage	4.36	4.20	3.20	30	Two seasonal	Rice, other Kharif crops, and other Rabi crops
Storage	12.12	8.08	4.81	80	Perennial	Sugarcane, Garden & Orchards, Rice, Maize, Millets, Wheat, Gram, other Kharif and Rabi crops

Appendix

1	2	3	4	5	6
34.	Rojki	Bhavnagar	2.70	Rojki	1966
35.	Suvi	Kutch	2.05	Suvi	1966
36.	Bhogavo-II (Wadhwan)	Surendranagar	7.24	Bhogavo	1966
37.	Hiran	Junagadh	8.07	Hiran	1966
38.	Aji	Rajkot	6.85	Aji	1969
39.	Dantiwada (Banas)	Banaskantha	108.79	Banas	1969
40.	Shetrunji (Khodiar)	Amreli	16.32	Shetrunji	1969
41.	Niruna	Kutch	5.01	Bhurad	1969
42.	Vartu	Jamnagar	4.98	Vartu	1969
43.	Bhadar	Rajkot	42.80	Bhadar	1969
44.	Ghelo	Bhavnagar	3.14	Ghelo	1969
45.	Sapda	Jamnagar	1.77	Bhagadi	1969

N.A.—Not available.

Source: (1) Irrigation Statistics (1960-61)—Central Water and Power Commission.
(2) India—Irrigation and Power Projects (Five Year Plans), Central Water and Power Commission (April, 1970).
(3) Note Volumes of Irrigation Chapter—Central Water and Power Commission (Rajasthan and Gujarat States)—1970 (unpublished).
(4) Replies of the Gujarat and Rajasthan States to the Questionnaire issued by the Irrigation Commission.

17.2—*Contd.*

7	8	9	10	11	12	13
Storage	4.10	2.59	1.54	29	Two seasonal	Other Kharif and Rabi crops
Storage	4.70	3.19	1.34	9	Two seasonal	Other Kharif and Rabi crops
Storage	0.73	0.73	0.61	N.A.	N.A.	N.A.
Storage	8.09	3.10	2.63	N.A.	N.A.	N.A.
Storage	18.21	8.90	1.71	N.A.	N.A.	N.A.
Storage	80.94	52.61	44.52	652	Perennial	Garden & Orchards, other Kharif and Rabi crops
Storage	11.59	9.86	7.69	24	Perennial	Garden & Orchards, Rice, other Kharif crops, Wheat and Gram
Storage	3.64	3.04	5.67	16	Two seasonal	Other Kharif and Rabi crops
Storage	3.77	3.03	3.17	N.A.	N.A.	N.A.
Storage	27.74	26.66	18.06	84	Perennial	Sugarcane, Garden & Orchards, Rice, Millets, Fibre crops, Wheat, Gram and other Kharif and Rabi crops
Storage	5.12	4.13	3.14	N.A.	N.A.	N.A.
Storage	1.21	1.12	1.01	6	Perennial	Sugarcane, Rice, other Kharif crops, and other Rabi crops

APPENDIX

Salient Features of Major and Medium Projects Under Construction in

				Time Schedule of Con-	
Sl. No.	Name of the Project	Zone/ District	Description of the Scheme	Date of commencement	Important items of work completed
1	2	3	4	5	6
Rajasthan					
1.	Angore	Sirohi	Construction of a storage dam on a tributary of the Luni River		Construction work not yet started
Gujarat					
2.	Gajansar	Kutch	Construction of an earthen dam 594 m long 17.7 m high, 3.2 km. south of Gajansar village and a canal 16 km. long on the left bank	1959	Headworks completed
3.	Rudra Mata	-do-	Construction of an earth dam 875 m long 27.4 m high across the Pus river 14 km. north of Bhuj town and canals on either side	1959	Headworks completed. Work on canal system in progress
4.	Kalindri	Junagadh	Construction of an earth dam 599 m long 18 m high across the river Kalindri, and canal system on right bank	1961	The project is in initial stage of construction

17.3

the Basin of the Luni and Other Rivers of Saurashtra and Kutch

struction	Cost				
Date of likely completion	Total cost Rs. million	Expenditure incurred Rs. million	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)
7	8	9	10	11	12
N.A.	2.01	Nil	N.A.	N.A.	1.21
IV Plan	2.00	0.95 (Mar. '69)	4.05	1.62	1.62
IV Plan	10.60	8.14 (Mar. '69)	5.40	4.05	7.20
IV Plan	4.30	0.07 (Mar. '69)	N.A.	1.56	0.91

Appendix

1	2	3	4	5	6
5.	Machhu II	Rajgarh	Construction of an earth dam 3,818 m long with a masonry spillway 206 m long in the gorge portion across the river Machhu near village Jodhpur and canal on the left bank	1961	Work on the Headworks in progress
6.	Goma	Bhavnagar	Construction of an earth dam 2784 m long 19.4 m high and a masonry waste weir 287 m long 7 m high across the river Goma about 4.8 km. from Paliyad village and canals on either side	1965	Headworks 60% completed. Canal systems 55% completed
7.	Saraswati	Mehsana	Construction of a 319 m long barrage-cum-bridge across the river Saraswati near Patna town and canal system on the left bank	1965	Headworks 46.5% completed. Canal system 26% completed
8.	Dhatarwadi	Bhavnagar	Construction of a dam across the river Dhatarwadi near village Bhakshi	—	Construction work not yet started

Source: (1) Note Volumes of Irrigation Chapter, 1970, C.W.P.C. (Rajasthan and Gujarat States)—Unpublished.

(2) Replies of the Gujarat and Rajasthan States to the Questionnaire issued by the Irrigation Commission.

17.3—*Contd.*

7	8	9	10	11	12
IV Plan	21.39	7.82 (Mar. '69)	12.3	9.00	7.69
IV Plan	8.50	4.60 (Mar. '69)	N.A.	4.00	2.19
IV Plan	21.20	9.45 (Mar. '69)	11.04	8.84	8.74
IV Plan	10.50	0.11 (Mar. '69)	N.A.	3.08	3.43

APPENDIX 17.4

New Schemes Included in the Fourth Plan Subject to Clearance by the Planning Commission

Sl. No.	Name of the Project	Zone/ District	Source of Supply (Name of river)	Estimated cost (Rs. million)	Ultimate irrigation ('000 hectares)	Remarks
1	2	3	4	5	6	7
Rajasthan						
			— nil —			
Gujarat						
1.	Sipu Reservoir Project	Banaskantha	Sipu tributary of the Banas	59.45	25.30	

Source: Replies of the Gujarat State to the Questionnaire issued by the Irrigation Commission.

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APPENDIX

Salient Features of Existing Major

Sl No.	Name of the Project	Zone/ District	Cost/ total expenditure incurred (Rs. million)	Source of supply (Name of river)	Year of completion	Type (flow/ storage lift)
1	2	3	4	5	6	7
Jammu and Kashmir						
1.	Ranbir Canal	Jammu	4.86	Chenab	1904	Flow
2.	Partap Canal	Jammu	0.60	Chenab	1904	Flow
3.	Martand Canal	Anantnag	0.79	Lidder Nallah (Jhelum)	1905	Flow
4.	Zaingir Canal	Baramulla	1.66	Madumati Nallah (Jhelum)	1931	Flow
5.	Kathua Canal	Kathua	7.66	Ravi	1961	Flow
6.	Partap Canal Remodelling	Jammu	14.80	Chenab	1961	Flow
Punjab						
7.	Sirhind Canal	Ludhiana & Patiala	26.87	Sutlej	1887	Flow
8.	Upper Bari Doab Canal	Gurdaspur	22.66	Ravi	1879	Flow
9.	Eastern Canal	Ferozepur	82.79	Sutlej	1933	Flow
10.	Harike Project	Ferozepur	91.45	Sutlej	1957-58	Flow
11.	Bhakra Nangal	Hoshiarpur	175.14	Sutlej	1963-64	Flow
Rajasthan						
12.	Gang Canal	Ganganagar	33.20	Sutlej	1928	Flow

Source: 1. Irrigation Statistics of India (1960-61)—Central Water and Power Commission—March, 1968.

2. Note volume of Irrigation Chapter on Jammu & Kashmir, Rajasthan, Haryana and Punjab—Central Water & Power Commission—March, 1970—Unpublished.

3. Replies of the State Governments of Jammu & Kashmir, Haryana and Rajasthan to the questionnaire issued by the Irrigation Commission.

18.1

and Medium Projects in the Indus Basin

G.C.A. ('000 hectares)	C.C.A. ('000 hects.)	Ultimate irrigation ('000 hectares)	Length of main canal and branches km.	Whether perennial, two seasonal or one seasonal	Cropping pattern	Remarks
8	9	10	11	12	13	14
N.A.	48.42	54.41	380.56	N.A.	N.A.	
N.A.	N.A.	6.07	N.A.	N.A.	N.A.	
3.89	3.81	3.76	84.49	N.A.	N.A.	
N.A.	4.94	4.94	78.86	N.A.	N.A.	
14.57	8.70	8.98	N.A.	N.A.	N.A.	
9.92	8.00	8.00	N.A.	N.A.	N.A.	
1854.83	1507.50	600.17	840	Perennial	Wheat & Cotton mainly	
536.37	490.09	335.17	468	Perennial	Maize, Millets, Wheat, Sugarcane & Cotton	
166.97	147.54	141.35	100	Perennial	Rice & Cotton mainly	
N.A.	N.A.	13.80	N.A.	N.A.	N.A.	
2170.45	1808.75	1459.18	1291	Perennial	Rice, Millets, Wheat,Gram & Cotton	These figures cover Haryana and Rajasthan also.
456.20	300.00	303.52	1502	Perennial	Wheat, Gram and Cotton	

APPENDIX

Salient Features of Major and Medium Projects

Sl. No.	Name of the project	Time schedule of construction			
		Zone/ District	Description of the scheme	Date of commencement	Important items of work completed
1	2	3	4	5	6
Jammu and Kashmir					
1.	Remodelling of Ranbir Canal—Phase-I	Jammu	The scheme envisages construction of silt ejector & widening of the canal from Head to Jammu Power House	1967-68	Investigation
2.	Dudhar Canal	N.A.	Construction of a canal 13 km. long from the Left Bank of Dudhar Nallah	1965	Canal physically completed except some minor work viz. water courses etc.
Punjab					
3.	Beas Unit-I Beas Sutlej Link	Punjab, Haryana & Rajasthan	Construction of a dam across river Beas at Pandoh. 26 km. long two tunnels and 12 km. long hydel channel	1961-62	About 60% of tunnels and 10% of hydel channel
4.	Beas Unit-II Pong Dam	,,	Construction of 100.6 km. high earthcore gravel dam and 5 tunnels	1961-62	100% excavation, 60% concreting

18.2

Under Construction in the Indus Basin

	Cost					
Date of likely completion	Total cost (Rs. million)	Expenditure incurred up to March 1969 (Rs. million)	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate Irrigation ('000 hectares)	Remarks
7	8	9	10	11	12	13
V Plan	5.50	0.56	N.A.	N.A.	20.40	
1971	4.25	2.15	N.A.	N.A.	2.83	
V Plan	1468.70	543.70	N.A.	N.A.	*320.00	*(For Punjab and Haryana)
V Plan	1676.70	664.57	N.A.	†650.00	††20.99	†For Punjab & Haryana. Besides benefits through Rajasthan Canal ††For Punjab only

Appendix

1	2	3	4	5	6
Rajasthan					
5.	Bhakra Irrigation	Ganganagar	The scheme is a part of the Bhakra Project. The State is constructing 1,468 km. of distribution system	1952	The scheme has been completed, only improvements are going on
6.	Rajasthan Canal	Ganganagar, Bikaner & Jaisalmer	Construction of 685 km. long canal	1958	178.3 km. long feeder completed. 77 km. of main canal along with the distributaries completed

Source: Note volumes of Irrigation Chapter on Jammu & Kashmir, Punjab, Haryana, Rajasthan—Central Water & Power Commission—March, 1970—Unpublished.

18.2—Contd.

7	8	9	10	11	12	13
1956	234.00	219.20 (up to Mar. '70)	N.A.	N.A.	230.68	
V Plan	110.20	615.10 (up to Feb. '70)	N.A.	N.A.	1264.28	

APPENDIX 18.3

New schemes included in the Fourth Plan

Sl. No.	Name of the project	Zone/ District	Source of Supply (Name of the river)	Estimated cost (Rs. million)	Ultimate irrigation ('000 hectares)	Remarks
1.	Tawi Lift Irrigation (Ravi-Tawi Lift Irrigation and Gravity Canal System—Phase I)	Jammu	Tawi	51.70	12.14	

Source: India—Irrigation and Power Project (Five Year Plans), Ministry of Irrigation and Power, April, 1970.

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APPENDIX 18.4

Salient Features of New Major and Medium Projects Proposed by the State Governments in the Indus Basin

Sl. No.	Name of the Project	Zone/District	Source of supply (Name of the river)	Estimated cost Rs. million	Ultimate Irrigation ('000 hectares)	Remarks
Jammu and Kashmir						
1.	Ravi-Tawi Lift Irrigation and Gravity Canal System—Phase II	Jammu	Ravi and Tawi	168.30	36.42	
2.	Latpora Lift Irrigation	Kashmir	N.A.	2.85	N.A.	
3.	Remodelling Tongri Canal	Kashmir	N.A.	2.00	N.A.	
4.	Remodelling May Khul	Kashmir	N.A.	2.00	N.A.	
5.	Remodelling Sanigul Khul	Kashmir	N.A.	2.00	N.A.	
6.	Pargwal Canal	Jammu	N.A.	4.06	2.94	
7.	Manawar Tawi Lift Irrigation	Jammu	Manawar Tawi	6.00	3.24	
8.	Pantial Canal	Jammu	N.A.	3.60	2.43	
9.	Naj Canal	Kandi Area	N.A.	2.50	N.A.	
10.	Ranjan Lift Scheme	Kandi Area	N.A.	8.00	N.A.	
Haryana						
11.	Link Works to transport the Ravi and Beas Waters to the W.Y.C. system	Haryana	Ravi and Beas	27.02	—	No direct benefits
12.	Dadri Lift Irrigation	Gurgaon	Ravi and Beas	7.57	15.30	
13.	Nahar-Salawas Lift Scheme	N.A.	Ravi and Beas	5.75	6.30	
14.	Sohna Lift Irrigation Scheme (Stage II and III)	Gurgaon	Yamuna, Ravi and Beas	N.A.*	78.70	*The project is under investigation

Punjab					
15. Thein Dam	Punjab	Ravi	880.00†	N.A.	†Total cost; share of irrigation is not available.
16. Extension of Non-perennial Irrigation in U.B.D.C.	Amritsar & Gurdaspur	Ravi	27.28	43.71	
17. Utilisation of the Ravi Beas waters	Punjab & Haryana	Ravi and Beas	18.66	253.75	
18. Sinking of Tubewells in the U.B.D.C. tract for stabilising and augmenting supplies in winter	Gurdaspur & Amritsar	—	24.00	40.47	
Rajasthan					
19. Increasing irrigation potential on the Gang Canal system	Bikaner	Ravi and Beas	26.00	101.00	
20. Increasing irrigation potential on the Bhakra Canals	Ganganagar	Ravi and Beas	30.00	125.00	
21. Creating potential for rice cultivation on the Bhakra Canals	Ganganagar	Ravi and Beas	3.00	8.10	
22. Sidhmukh Project	Ganganagar	Ravi and Beas	6.45	75.60	
23. Nohar Project	Ganganagar	Ravi and Beas	70.85	54.72	

Sources: (i) Report of the Working Group on Irrigation and Flood Control, Fourth Five Year Plan (1969-74) and Annual Plan (1969-70) for Himachal Pradesh, Haryana, Jammu and Kashmir, Punjab and Rajasthan.

(ii) India—Irrigation and Power Projects (Five Year Plans), Central Water and Power Commission (April, 1970).

(iii) Replies of Haryana and Rajasthan States to the questionnaire issued by the Irrigation Commission.

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